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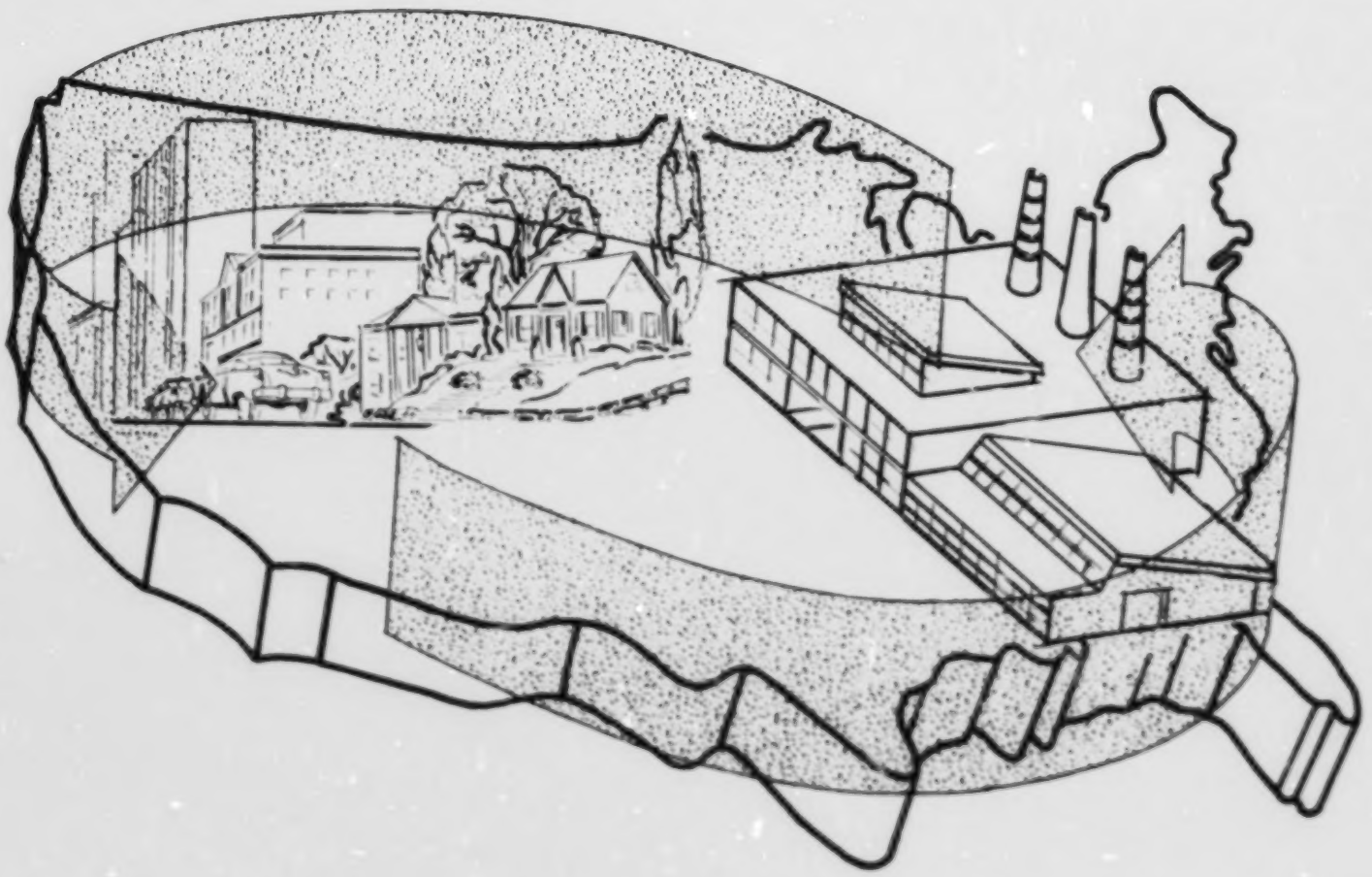
PARKERSBURG, WEST VIRGINIA – MARIETTA, OHIO, AIR POLLUTION ABATEMENT ACTIVITY

SUPPLEMENTAL TECHNICAL REPORT



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This report is based on an investigation of air pollution in the Parkersburg, West Virginia - Marietta, Ohio area for the period March 1967 to August 1969 and has been prepared as a supplement to the March 1967 technical report. Together these two reports are intended to assist the governmental agencies concerned with such air pollution in their consideration of the following:

1. The occurrence of air pollution subject to abatement,
2. The adequacy of measures taken toward abatement of pollution,
3. The nature of the delay, if any, in abating pollution,
4. The necessary remedial action, if any.

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Exhaust emissions	Gas sampling	
Sulfur dioxide	Samplers	
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Inventories	Experimental data	
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Public Health Service
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National Air Pollution Control Administration
Durham, North Carolina
September 1969

FOREWORD

This report is based on an investigation of air pollution in the Parkersburg, West Virginia - Marietta, Ohio area for the period March 1967 to August 1969 and has been prepared as a supplement to the March 1967 technical report. Together these two reports are intended to assist the governmental agencies concerned with such air pollution in their consideration of the following.

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PARKERSBURG, WEST VIRGINIA – MARIETTA, OHIO, AIR POLLUTION ABATEMENT ACTIVITY

SUPPLEMENTAL TECHNICAL REPORT

I. INTRODUCTION

REVIEW OF ABATEMENT ACTION

On March 22, 1967, the Parkersburg, West Virginia - Marietta, Ohio, Interstate Air Pollution Abatement Conference was convened at the Vienna Community Building in Vienna, West Virginia, and continued in session through March 23, 1967. The conference was called by the Secretary of Health, Education, and Welfare relative to air pollution originating in Ohio and allegedly endangering the health and welfare of persons in Vienna, West Virginia.

In preparation for the conference, a technical investigation of several months duration was conducted by the Abatement Program, Division of Air Pollution, U.S. Public Health Service, in cooperation with the West Virginia Air Pollution Commission and the Ohio Department of Health. Data and information from the survey were included in a technical report made available to official participants for use at the conference. Information contained in the technical report and subsequent presentations at the conference documented the existence of particulate and sulfur dioxide pollution originating in both states, transcending state boundaries, and affecting health and welfare of residents in the adjoining state. Furthermore, the major sources of pollutants were identified and applicable control measures were described.

On March 24, 1967, following presentation of data and information by the conference participants and others who had requested the opportunity to appear, the participants set forth certain general conclusions and findings and a series of recommendations considered to be cogent and pertinent to the air pollution abatement needs of the conference area. The recommendations were based on data showing that air contaminant emissions from industrial operations and solid-waste disposal

practices, because of inadequate source control and unfavorable meteorological and topographical conditions for dilution and dispersion of pollutants, resulted in excessive levels of pollution which endanger the health and welfare of persons in Vienna, West Virginia, and other residents of the bi-state area. A copy of the recommendations of the conference appear in Appendix A.

Although the conference participants generally concurred in the recommendations, disagreement was expressed with certain provisions by the official participants of the states at the announcement session as follows:

1. Mr. Carl G. Beard, II, Executive Secretary of the West Virginia Air Pollution Control Commission and official representative of State of West Virginia, expressed concern that the rigid compliance period was not realistic for all industries in West Virginia and would create hardship for some. He suggested an alternative plan such as a phased program of compliance.

2. Mr. Jack A. Wunderle, of the Ohio Air Pollution Control Board and official representative of the State of Ohio, stated reservations as to both the time period for compliance and the limitations established in the recommendations.

While unanimous agreement in the conference recommendations by official participants is the goal of the conference, it is not a prerequisite for adoption of the recommendations by the Secretary. Nevertheless, the divergent viewpoints of the participants should be reconciled, if possible, for effective implementation of the recommendations.

Added emphasis for reconvening the conference was further provided by the following considerations and events:

1. On April 17, 1967, Dr. Emmett V. Arnold, Director of Health, Ohio State Department of Health, requested of the Secretary that issuance of final recommendations be delayed "until investigative, inquisitive research, and evaluation study can be conducted to form the basis for such recommendations."

2. Procedural questions were raised by the Attorney General of West Virginia regarding implementation of the 1967 conference and formation of the conference recommendations.

3. Substantial differences, which had not been fully resolved at the conference, existed between emission data supplied by the Union Carbide Corporation and data developed by the National Air Pollution Control Administration (formerly Division of Air Pollution, U.S. Public Health Service).

4. New complaints of air pollution problems not covered in the scope of the

1967 conference were brought to the attention of the National Air Pollution Control Administration (NAPCA) and the states of Ohio and West Virginia in April of 1968. Copies of a petition containing signatures of over 800 residents in the South Belpre, Porterfield, and Little Hocking, Ohio, area were received by the Ohio Department of Health and West Virginia Air Pollution Control Commission. The petition, sponsored by the Little Hocking Community Club cited odorous and irritant pollutants emanating from industrial plants as a major concern to residents in Belpre Township of Washington County, Ohio.

Recommendations of the conference were withheld by the Secretary pending resolution of these matters.

RECENT SURVEY ACTIVITIES

Formal action was taken to reconvene the conference on December 17, 1968. Consultation was held on that date with representatives of Ohio Air Pollution Control Board and West Virginia Air Pollution Control Commission. At the consultation meeting it was agreed that the conference should be reopened and additional investigative activities should be undertaken to provide additional data or more refined data, which would define in greater detail the distribution and extent of sulfur dioxide pollution in the area and to obtain basic information on the odor and irritant problems reported in the Belpre Township, Ohio, and the Lubeck District, West Virginia, region of the abatement activity area.

Relative to reopening the conference, field investigative activities were initiated by NAPCA to obtain technical data and information necessary to update and supplement that contained in the 1967 technical report. These activities and their objectives were as follows:

1. Additional measurements of sulfur dioxide pollution through area saturation sampling using sulfation plate measurements and aerial sampling from light aircraft. Data developed by these tests were used to determine spread of SO_2 over the survey area and the transport and diffusion of SO_2 emissions from large sources.

2. Updating of air contaminant emission inventory to reflect current emission quantities from the various source categories surveyed in 1966 and to determine whether significant changes have occurred in type and quantity of pollutant emissions in the 2-year period since the initial survey.

3. General survey of the condition of vegetation in the area and particularly in the vicinity of major sources of pollutants to determine the extent of air pollution injury to vegetation and changes in types of injury and areas

affected as reported in 1967.

4. Obtain from Union Carbide Corporation updated and sufficiently detailed information relative to process changes, expansion of facilities, or addition of control equipment that would permit accurate assessment of current emissions.

5. Perform an odor and irritant survey in the vicinity of Washington, West Virginia, and Little Hocking and Porterfield, Ohio, to obtain evidence of the presence, types, frequency, and intensity of any odors and sensory irritants causing lachrymation or nasal and throat discomfort and identify the possible sources of any odors or irritants detected.

The air pollution control agencies of the states of West Virginia and Ohio agreed to conduct additional air quality sampling in their states. The Ohio Department of Health established and operated air sampling stations for a 4-month period in the Little Hocking - Porterfield, Ohio, area. Routine measurements were made for suspended particulates, dustfall, and sulfation. Measurements, including both air quality and wind, were already being taken at several sites in the Lubeck District by the West Virginia Air Pollution Control Commission.

The survey activities as described were initiated in January 1969 and continued through August 1969. The results of the survey efforts carried out by NAPCA are reported herein. Air quality data obtained from the survey activities of the cooperating agencies are not included and will be reported separately by each state agency. Data and information contained in this report are presented as a supplement to the 1967 pre-conference technical report for the Parkersburg, West Virginia - Marietta, Ohio, Air Pollution Abatement Activity Area.

II. CURRENT INVENTORY OF AIR CONTAMINANT EMISSIONS

The emissions inventory data compiled for the Parkersburg, West Virginia - Marietta, Ohio, Abatement Activity Area in 1966 showed that large industrial point sources accounted for 98 percent of the sulfur oxides and 94 percent of the particulate emissions. In the 2-year period following the conference, new industrial development, expansion of existing plant facilities, and addition of control devices on pollution sources have altered air contaminant emissions in the area.

Consequently, the various source categories listed in the 1967 technical report were resurveyed to determine air contaminant emissions in the general area in 1969 and changes in emissions from specific sources. Industrial plant officials were asked to furnish emission estimates or information from which estimates could be made for their present plant operations. City and county officials were recontacted to determine changes in waste disposal practices and community patterns that could affect emissions from area sources. Based on the most recent information, emission estimates for each source category were adjusted to reflect current emission quantities.

POLLUTANT EMISSIONS FROM POINT SOURCES

Emission inventory data obtained from the 1969 industrial survey are given in Table 1. Pollutant emissions calculated for plants inventoried in 1966 are included in the table for comparing emission rates in the two periods. The more recent inventory data show 93,140 pounds per day of particulates and 339,380 pounds per day of sulfur oxides being emitted in the survey area annually by point sources. This represents an overall increase of 29 percent in particulate emissions and 2 percent in sulfur oxides emissions over emission rates estimated in 1966.

The Amax Specialty Metals Corporation has been added to the point source list on the basis of more recent data. A new plant, Ashland Chemical Company, a Division of Ashland Oil and Refining Company, began operation near Belpre, Ohio, in 1969. Particulate and SO_2 emissions from the carbon black plant are not appreciable; however, quantities of sulfide gases and other sulfur compounds emitted from the process could cause localized odor problems. Applicable control techniques for the plant are discussed in this report.

Table 1. ESTIMATED OR REPORTED POINT SOURCE EMISSIONS IN STUDY AREA (pounds per day)

Source		Combustion of fuels		Process emissions		Refuse disposal		Total emissions	
		Particulate	SO_2	Particulate	SO_2	Particulate	SO_2	Particulate	SO_2
Ohio									
American Cyanamid Co.	- 1965	320	1,170	-	-	6	-	326	1,170
(Marietta Township)	- 1968	320	1,170	-	-	6	-	326	1,170
B. F. Goodrich Co.	- 1965	725	2,840	5	-	-	-	730	2,840
(Muskingum Township)	- 1968	725	2,840	5	-	-	-	730	2,840
Shell Chemical Co.	- 1965	1,270	33,300	-	-	-	-	1,270	33,300
(Belpre Township)	- 1968	1,470	39,980	-	-	-	-	1,470	39,982
Union Carbide Corp.	- 1965	17,044	237,000	17,000[a]	9,350	16	-	34,060	246,350
Metals Division	- 1968	17,044	237,000	27,230[b]	9,350	16	-	44,290	246,350
Plastics Division	- 1965	18	-	-	-	260	-	278	-
(Warren Township)	- 1968	18	-	-	-	-	-	18	-
Ohio total	- 1965	19,377	274,310	17,005	9,350	282	-	36,664	283,660
	- 1968	19,577	280,992	27,235	9,350	22	-	46,834	290,342
West Virginia									
E.I. duPont de Nemours Co.	- 1965	5,500	25,000	1,650	-	600	-	7,750	25,000
(Lubeck District)	- 1968	3,390	29,482	2,245	-	600	-	6,235	29,482
FMC Corp. American Viscose Division	- 1965	21,000	25,000	-	-	7	-	21,007	25,000
(Tygart District)	- 1968	32,770	19,400	504	-	-	-	33,274	19,400
Johns-Manville Fiber Glass Inc.	- 1965	65	2	645	-	-	-	710	2
(Vienna)	- 1968	-	-	680	-	-	-	680	-
Amax Corp.	- 1965[c]								
(Lubeck District)	- 1968	-	-	2,800	165	-	-	2,800	165
West Virginia total	- 1965	26,565	50,002	2,295	-	607	-	29,467	50,002
	- 1968	36,160	48,882	6,229	165	600	-	42,989	49,047
Study area total	- 1965	45,942	324,312	19,300	9,350	889	-	66,131	333,662
	- 1968	55,737	329,874	33,464	9,350	622	-	89,823	339,389

[a]Reported.

[b]Estimated.

[c]Not calculated.

Industrial operations having significant changes in emissions, whether increased or decreased amounts, are discussed below.

The American Cyanamid Company, an organic chemical manufacturer, showed no change in emissions in the first half of 1969, but in June 1969, the plant changed from coal to gas fuel and reduced emissions of particulate matter and sulfur oxides. Daily reduction of emissions amount to 310 pounds of particulate matter and 1170 pounds of sulfur oxide.

Other gaseous pollutants such as hydrogen chloride, methyl chloride, ammonia, organic sulfides, and sulfur trioxide are emitted from this plant. These gaseous process emissions may create potential corrosion, odor, and lachrymator problems when poor atmospheric diffusion conditions exist and/or when plant equipment does not operate properly.

The Shell Chemical Company plant in Belpre Township, a manufacturer of polyisoprene and polystyrene, used more coal in steam-generating boilers in 1968 than was used in 1965. Estimates of daily atmospheric emissions in 1968 were 1470 pounds of particulate matter and 40,000 pounds of sulfur oxides. In May 1969 the plant started using coal with less ash and sulfur. Estimates of present daily emissions are 1070 pounds of particulate matter and 19,200 pounds of sulfur oxides. The use of lower sulfur coal along with modern dust-control devices, including electrostatic precipitators in the steam plant, have reduced emissions.

Process emissions include styrene and toluene wastes; the estimated emission of styrene is 160 pounds per day.*

The Union Carbide Corporation, Mining and Minerals Division, a manufacturer of ferro-alloys, was in 1965 and is still in 1968, the largest emitter of both particulate matter and sulfur oxides in the study area. Union Carbide in 1965 reported daily emissions of 34,000 pounds of particulate matter. NAPCA estimates in 1966 based on emission data from similar refining operations indicate daily emissions of 61,000 pounds of particulate, with 44,000 pounds from ferro-alloy furnaces and the balance from coal-fired boilers.

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*Experience and information reported in the literature have shown that when present in the atmosphere in low concentration, these chemical substances, either singly or in combinations, have been associated experimentally and under naturally occurring conditions with odor or lachrymation problems. The relationship of these specific pollutants to area complaints of this nature is more fully discussed in later sections of the report.

Federal requests in 1968 and 1969 to Union Carbide for additional data concerning emissions of particulate and sulfur dioxide from the ferro-alloy plant did not yield the desired data. Recently a representative of the Ohio Air Pollution Control Board, too, attempted to obtain such data from the corporation and was unsuccessful.

NAPCA estimates in 1969, again made on the basis of available information and best engineering judgment, show total plant emissions of 44,200 pounds per day of particulate matter. Estimates of particulate emissions from the ferro-alloy process were made with the knowledge that 11 furnaces are now used. Emissions from two furnaces pass through high-energy scrubbers; the other furnaces are not controlled. Emissions from ferro-alloy furnaces are estimated to have been reduced to 27,200 pounds per day of particulate matter. The 17,000 pounds of particulate matter per day from the coal-fired boilers is assumed to have remained the same as that of 1965.

The daily emission of sulfur dioxide from fuel combustion and the ferro-alloy process in 1965 and 1968 is estimated to be 246,000 pounds.

The E. I. du Pont Company, manufacturer of fluorocarbons, Nylon and other resins, and polyvinyl sheeting, in 1968 increased their consumption of coal. It is estimated that the plant emits daily 6230 pounds of particulate matter and 29,500 pounds of sulfur dioxide.

Process emissions include gaseous pollutants such as formaldehyde, methylene chloride, and acetic acid.*

The FMC Corporation, American Viscose Division, a manufacturer of Rayon fiber used more coal in the power facility in 1968 than that used in 1965. Estimates of daily atmospheric emissions from the entire plant are 32,800 pounds of particulate matter and 19,400 pounds of sulfur oxides. Use of lower sulfur coal in 1968 reduced the emission of sulfur oxides.

Process emissions include gaseous pollutants such as hydrogen sulfide and carbon disulfide, which can create potential corrosion and odor problems.

The Borg-Warner Corporation, Marbon Chemical Division, a manufacturer of ABS plastic, uses gas fuel for generation of heat and steam and has negligible emissions of particulate matter and sulfur oxides.

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*See footnote on page 6.

Process emissions include acrylonitrile and styrene, which by themselves and/or in combination with other gases from close industrial neighbors create potential lachrymators.* Estimates of daily emissions are 930 pounds of acrylonitrile and 910 pounds of styrene.

The Amax Specialty Metals plant produces such metals as zirconium and hafnium in a complex metallurgical and chemical process.

Emissions from the power facility are not considered a problem since gas is used as a fuel. Emissions from the process do not have a uniform rate since many of the operations are batch and discharge intermittently at peak rates.

Amax estimates 500 tons per year of particulate matter, which is largely silicon dioxide (SiO_2), is emitted from the electric arc furnace. Approximately 29 tons per year of other particulate matter is emitted elsewhere in the process. The daily peak of particulate matter is estimated at 2800 pounds.

Other process operations discharge approximately 58 tons per year of chlorine,* or about 328 pounds per day. Peak chlorine rates of as much as 45 pounds per hour were reported.

The electric arc furnace contributes most of the plant emissions of particulate matter. Emissions from electric arc furnaces in similar operations have been successfully controlled in other areas by the use of fabric filters, electrostatic precipitators, and high-energy scrubbers.

The Ashland Chemical Company, Division of Ashland Oil and Refining Company, a manufacturer of carbon black, uses gas as a fuel in its power facility with no significant emissions of particulate matter and sulfur oxides. Process emissions of 992 pounds of sulfur per day are emitted as miscellaneous sulfur compounds, which are judged to be largely hydrogen sulfide and sulfur. Feed stock to the process, coke oven creosote, is about 0.86 percent sulfur.[1] Carbon black plants analogous to this plant have reported 300 to 400 ppm of hydrogen sulfide and 200 to 400 ppm of sulfur in process effluents.[2]

Control of hydrogen sulfide emissions can be achieved by passing the effluent through a properly designed bubble-cap tower using an aqueous amine or caustic solution as scrubbing fluid.[3]

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*See footnote on page 6.

POINT SOURCES OUTSIDE OF SURVEY AREA

Four power plants outside the abatement activity area contacted during the course of the 1969 inventory submitted the emission estimates given in Table 2. Emissions from the four plants were not included in the area total because of their location outside of the survey area; however, the Muskingum River plant of the Ohio Power Company, because of its nearness to the area and large emissions, does have an impact on the air quality of the area. Recent expansion of facilities have nearly doubled plant generating capacity since the 1966 survey.

Table 2. EMISSIONS FROM LARGE POINT SOURCES LOCATED OUTSIDE OF STUDY AREA

Source	Emissions, lb/day	
	SO_x	Particulates
Ohio Power Company Muskingum River Plant Beverly, Ohio	1,435,760	375,654
Appalachian Power Company Philip Sporn Plant New Haven, West Virginia	774,872	193,280
Ohio Valley Electric Corporation Kyger Creek Plant	1,255,325	49,978
Monongahela Power Company Willow Island Plant St. Mary, West Virginia	333,800	58,433

POLLUTANT EMISSIONS FROM AREA SOURCES

A significant decrease in the emissions from area sources has resulted from conversion of the privately operated, open-burning dumps in Washington County into sanitary landfills.

The solid-waste disposal law enacted by the State of Ohio on January 1, 1969, prohibits open burning of refuse. When the dumps serving Marietta and other municipalities in Washington County were brought into full compliance by August 1969, more than 700 pounds per day of particulates previously emitted from these sources to the atmosphere in the survey area was eliminated. Similar restrictions against open burning of car bodies at scrap-metal reclaiming yards in Washington County have brought additional improvements in reduction of odor and dark smoke emissions.

Solid-waste regulations enacted by West Virginia became effective in July 1969. Although the bulk of industrial and municipal wastes in Wood County are disposed of in sanitary landfills, backyard burning by individuals is still permitted.

Emissions from other area sources such as residential, commercial, and governmental fuel burning and mobile sources were assumed to remain at the estimated 1966 level. Sufficient time had not lapsed since the previous survey for area growth to alter appreciably emission quantities.

POLLUTANT EMISSIONS OTHER THAN SULFUR DIOXIDE AND PARTICULATES

Pollutants other than sulfur oxides and particulates that cause, or may cause, adverse effects are released in the area. These include odorous, corrosive, and irritant pollutants characteristic of emissions from specific industries in the area.

Odor nuisance problems caused by the release of odorous and highly objectionable sulfide gases were mentioned in the 1967 technical report. Adverse effects of hydrogen fluoride and chlorine on indigenous vegetation are described in this report. Air contaminants emitted in the area capable of causing lachrymation problems are also discussed. However, in view of the wide variety of complex organic and inorganic materials processed or produced by the chemical industries in the area, it is likely that other odorous, corrosive, or irritant pollutants are periodically or accidently released in the area and cause intermittent degradation of the atmosphere.

III. MEASUREMENTS OF SULFUR DIOXIDE

DISTRIBUTION OF SULFATION RATE MEASUREMENTS

Lead peroxide plates were exposed at 232 locations in the study area to determine the distribution of sulfation rate[4]. Sulfation rate, an indication of sulfur dioxide dosage, can be used to estimate the monthly average sulfur dioxide concentration. The plates were exposed on utility poles about 10 feet above the ground for intervals of approximately 30 days starting at the beginning of the months of April and May 1969. The plates were exposed at locations shown in Figure 1. Appendix C contains a tabulation of the results.

The geographical distributions of sulfation rate for the months of April and May, 1969, are shown in Figures 2 and 3. In both months areas of maximum sulfation rates were found downwind of two large sources of sulfur dioxide: the Union Carbide plant and the Beverly Power Plant. The highest sulfation rate (7.2 mg SO_3/100 cm^2-day) was measured in the vicinity of Union Carbide. A contribution of industrial installations in the Washington Bottom area was detected as well.

The interstate nature of the pollution is particularly evident in the area between Vienna and Williamstown. From the center of high concentrations, on the Ohio side of the river, an area of contamination extends to the northeast through southeast in April and to the east and northeast in May. These extensions are reflections of the prevalent wind directions. Note the wind roses in the lower right of the sulfation maps.

An area of higher concentrations is shown to the west of Marietta and to the north of highway U. S. 50 during both months. The terrain in the area is about 300 feet above the Ohio River. When winds are southerly and the atmosphere stable, the plume of the Union Carbide plant reaches the surface in this area while still coherent and concentrated. The aircraft-acquired data shown in Figures 4-A and 5 document a period when sizeable concentrations were occurring in the area.

When winds are northwesterly, the area north of U. S. 50 is downwind of the Beverly Power Plant. The power plant's contribution assists in explaining the similarity in the April and May sulfation levels. Northwesterly winds were less

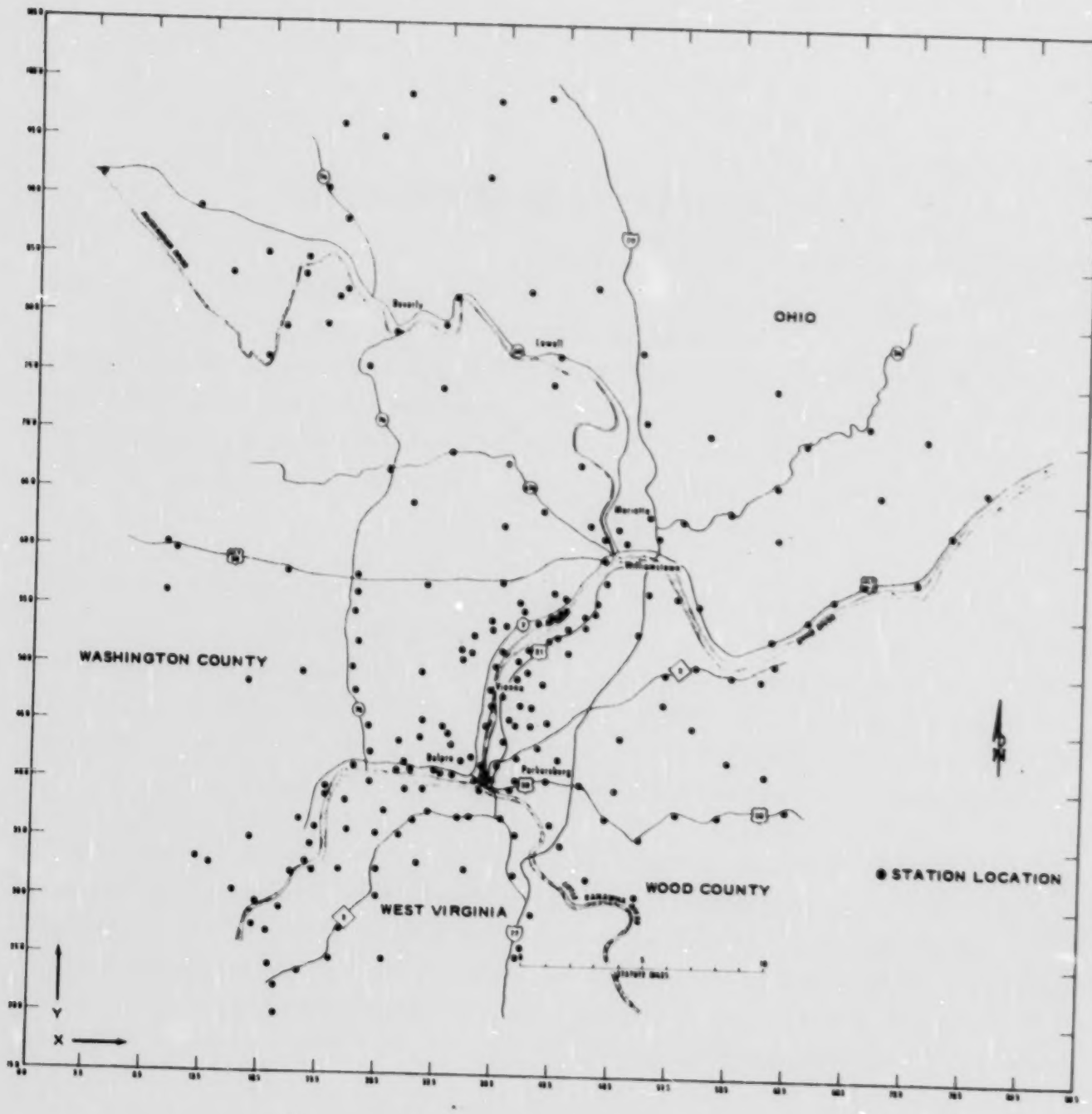

Figure 1. Sulfation-plate sampling network.

frequent, but southerly winds were much more frequent in May than in April. The area was downwind of one of the two major sources more than 25 percent of the time.

Frequent contamination of this area was indicated by the lead peroxide candle data collected in 1965 and 1966 (see Table D-IV, p. 81, of the March 1967 technical report). The average sulfation rate in 1965 and 1966 was highest at the Marietta (West) site, located nearest the area of high sulfation rates, north of U. S. 50, found in April and May, 1969. It is also noted that none of the continuous sulfur

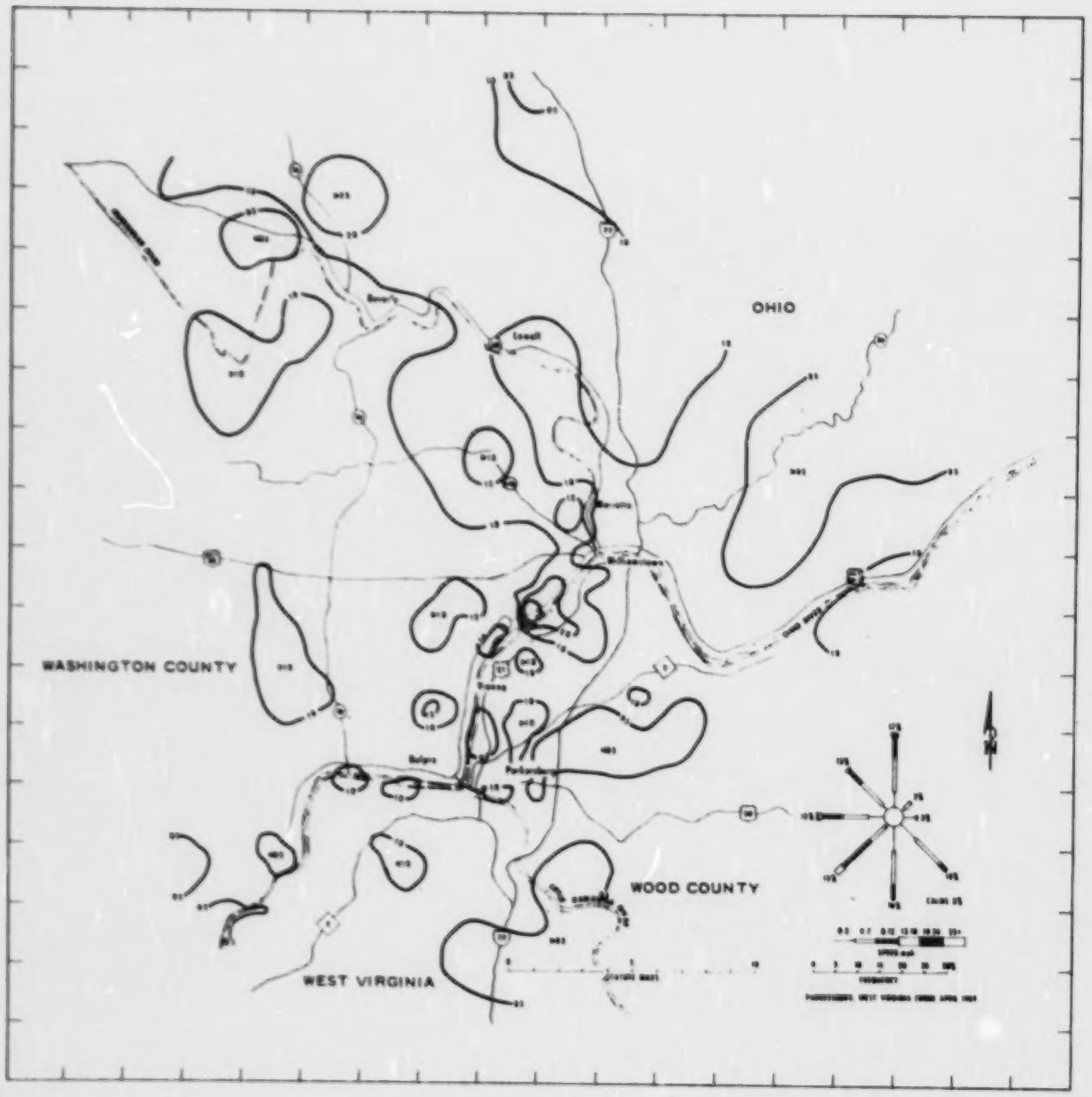

Figure 2. Distribution of sulfation rate for April 1969 (mg SO_3/100 cm^2-day).

dioxide measurements obtained in 1965 and 1966 were taken in the areas showing high sulfation rates.

In summary, most of the interstate area experiences readily detectable levels of sulfation. Pollution levels in portions of the area subject to the greatest contamination are related to two known sources of sulfur dioxide.

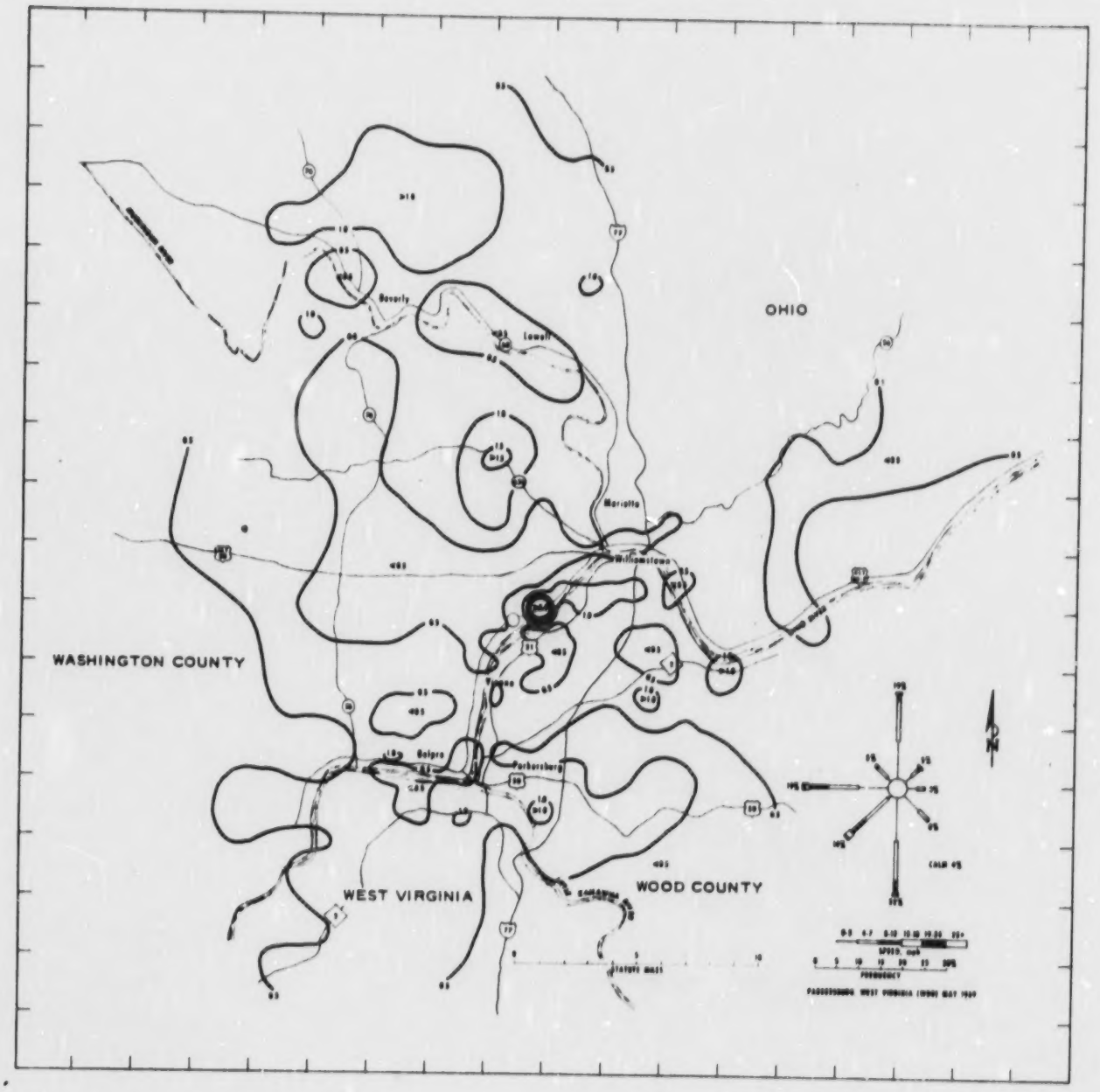

Figure 3. Distribution of sulfation rate for May 1969 (mg SO_3/100 cm^2-day).

CASE STUDIES OF DISTRIBUTION OF CONTAMINANTS

Aerial sampling for air pollutants was conducted in the Parkersburg-Marietta area for short periods in November 1968 and January 1969. The purpose was (1) to determine the distance contaminants from known sources could be traced, (2) to observe the height contaminants were mixed in various weather conditions, and (3) to ascertain whether some portions of the area might be more subject to contamination than those where air quality data had been collected in the past.

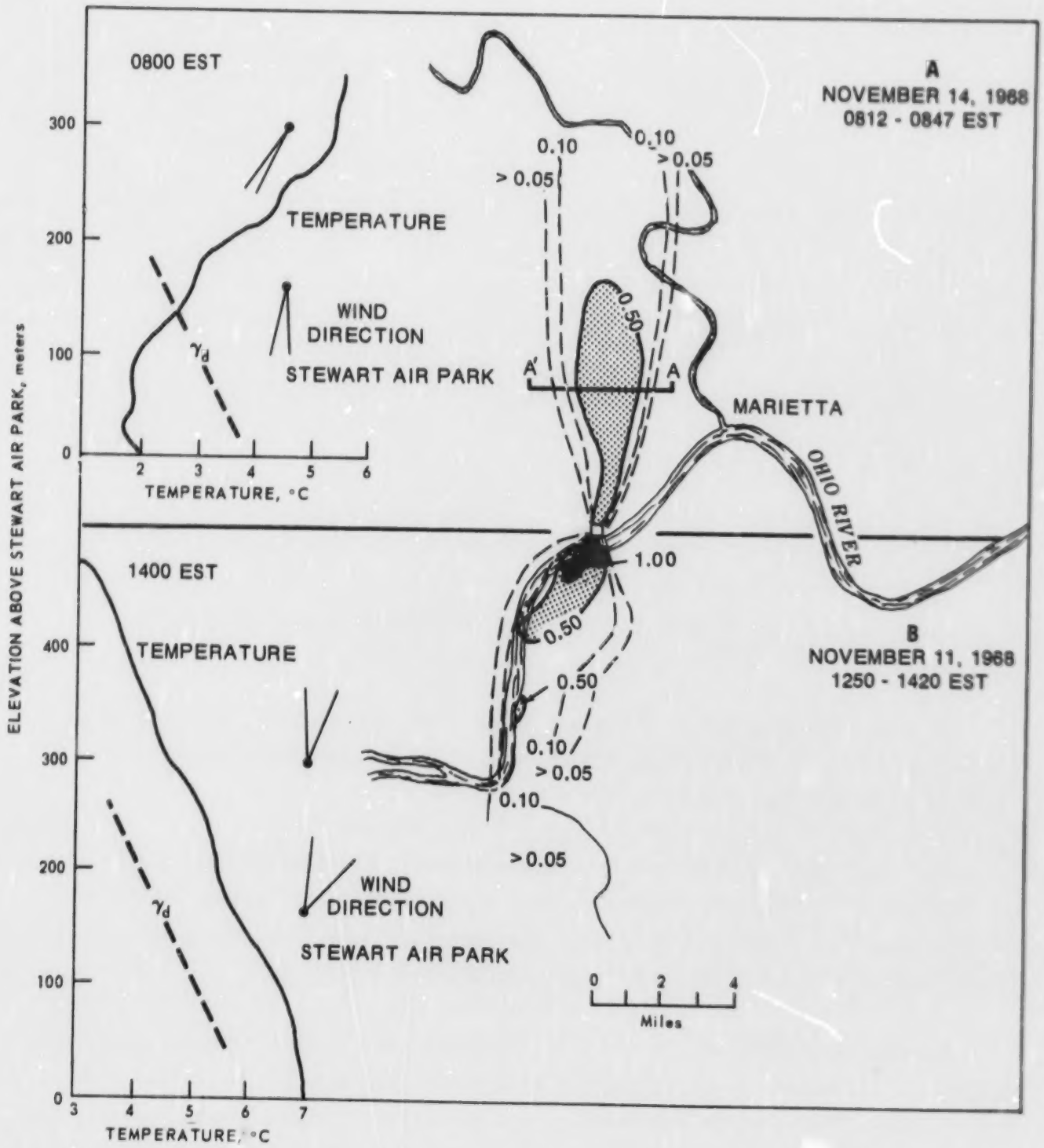

Figure 4. Plan view of sulfur dioxide plume from Union Carbide power plant on November 14, 1968 (A), and November 11, 1968 (B) (concentrations in parts per million).

A helicopter instrumented with fast-response sulfur dioxide, temperature, and altitude sensors was used from November 11 to 14, 1968. A light, fixed-wing aircraft was flown on January 8 through 12, 1969. The aircraft carried a particulate sensor in addition to the sulfur dioxide, temperature, and altitude sensors. The equipment and sampling procedures are described in Appendix B.

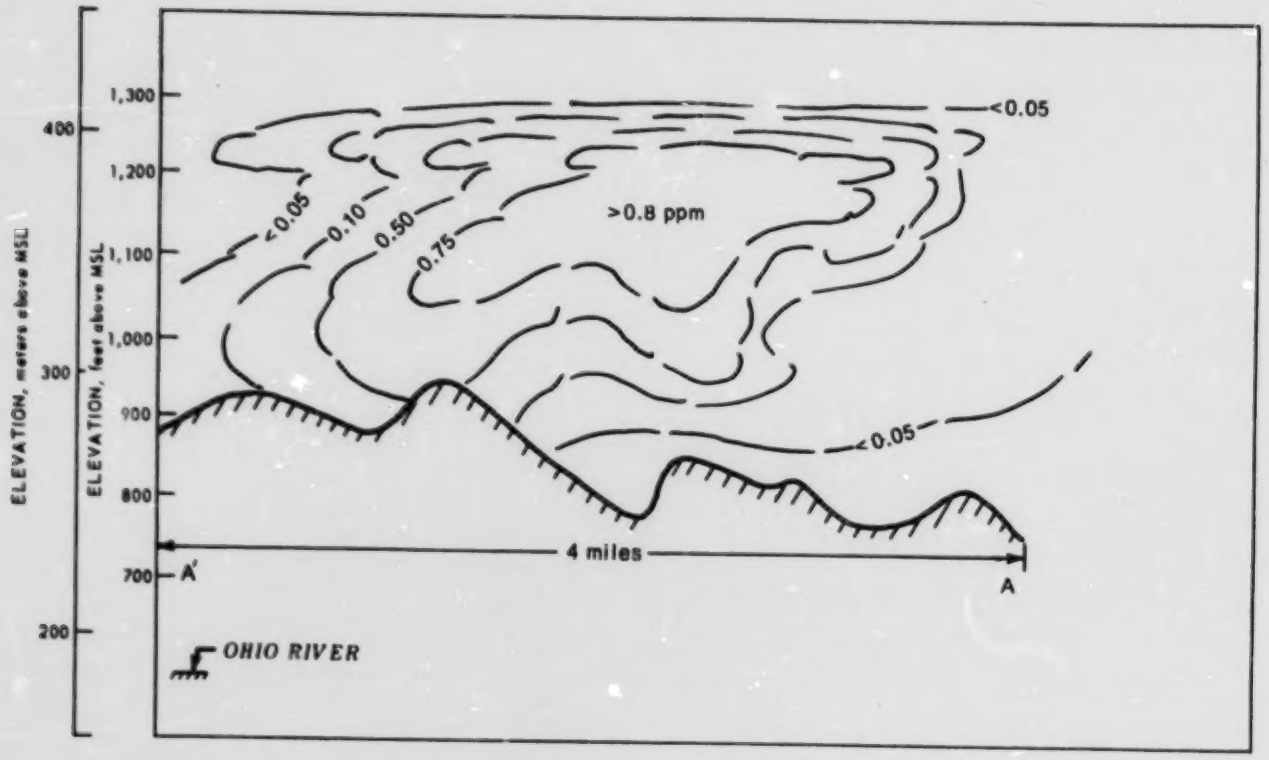

Figure 5. Cross section of sulfur dioxide plume from Union Carbide power plant on November 14, 1968 (see Figure 4).

On some days when the aircraft was being used, air samplers operated in a mobile van measured ground-level concentrations of contaminants beneath areas in which the aircraft was detecting the plumes.

Four days were selected for detailed analysis: November 11, 13, and 14, 1968, and January 11, 1969. The weather on each day differed from weather on the others in some important aspect. The weather was generally highly favorable for the rapid dispersion of air pollution on all days except November 14, 1968.

November 11, 1968, was the only day with persistent winds from the north and northeast. November 13 was a day with strong westerly and northwesterly winds at the surface. The atmospheric stability was neutral. November 14 was the only day with southerly winds; it was also the only day with a strong inversion close to the surface. January 11, 1969, was a day with neutral stability in the lower 1500 feet above the surface, above which the atmosphere became stable with minor inversions of moderate intensity. Wind speeds varied from 5 to 10 miles per hour, but the directions varied consistently with height from southwest near the ground to west-northwest at 1500 feet. Aerial sampling results for the 4 days are given below.

November 11, 1968

During the afternoon of November 11, the aerial survey was conducted in a triangular area bordered by Marietta, the Washington Bottom industrial area, and a point 5 miles south of the Wood County Airport. The SO_2 plume from the Union Carbide plant was carried down the Ohio River by the steady north to northeast winds at 500 to 1000 feet above the surface. The top of the plume reached 1500 to 1600 feet. Within 1-1/2 miles of the plant, SO_2 concentrations in the plume exceeded 1.0 ppm. The plume was detected more than 8 miles from the plant, in the vicinity of South Parkersburg. See Figure 4-B.

While the helicopter was aloft a 2-1/2-hour ground survey for SO_2 was made in the Vienna area. The average concentration was 0.11 ppm. Short-period concentrations of 0.50 ppm were detected along Route 21 between 28th Street and 41st Street. Another area of higher levels (0.16 ppm for 30 minutes) was detected east of the City Building near 13th Avenue and 28th Street.

The plumes from Shell and DuPont intersected at plume level approximately 1 mile downwind of the stacks. The maximum concentration detected was 0.25 ppm.

November 13, 1968

The wind and stability were excellent for the rapid dispersion of pollution. The stability was approximately neutral up to 2000 feet shortly after sunrise. In the early afternoon neutral conditions were found up to 3200 feet, where the sounding was terminated because of strong winds and fuel limitations of the helicopter. Surface winds were gusty and averaged 14 miles per hour at Parkersburg during mid-afternoon hours. The direction was from the west to northwest. The winds aloft were consistently from the west-northwest. The speeds varied markedly. They were frequently measured at 20 to 30 miles per hour between 1000 and 2000 feet above the ground.

The plume from Union Carbide plant was "bent-over" quickly by the strong winds. Although it could be detected at low-levels by the sensor in the helicopter, the ground-level sensor detected a more remarkable feature of the impact of the emissions from this plant. The van cruised Route 21 from the Stewart Air Park north to Keller Lane, a distance of 6.2 miles, from 0831 to 1147 hours EST. It intersected the Union Carbide plume in the vicinity of Boaz three of the four times it passed the area. The SO_2 concentration reached 0.34 ppm once, and twice it reached 0.53 ppm. At 1413 the vehicle passed near Boaz again and a concentration of 0.39 ppm was detected.

When the helicopter was north and east of the Muskingum River, the plume from the Beverly Power Plant was clearly visible. The flight level was consistently between 1500 and 1700 feet above mean sea level, or slightly more than 500 feet above the higher terrain. Concentrations of 0.20 ppm SO_2 were measured over the Muskingum River, 5 miles upstream from its confluence with the Ohio River. The plume was detectable over Whipple, Ohio, which is 15 miles east-southeast of the power plant. While the helicopter was overhead, the ground-level mobile sampler sensed 0.12 ppm in the village.

November 14, 1968

The atmosphere was markedly stable on the morning of November 14. The temperature increased with height more than 5.5°F in the layer between 300 and 1000 feet above the Ohio River. The plume from Union Carbide rose to about 700 feet above the river and flowed northward under the steady winds from the south and south-southwest. A plan view of the plume is shown in Figure 4-A. The variation of temperature with height is shown on the left margin.

Several traverses were made of the plume at 2 and 4 miles north of the plant. Figure 5 shows a cross section of the plume derived from data gathered on the 4-mile traverse; in an area where the elevation of the ground is 200 to 350 feet above the river. The plume, confined by the inversion, intersected the higher terrain. Concentrations as high as 0.5 ppm were sensed at tree-top level on the highest terrain. A couple of hundred feet above the ground, concentrations exceeded 0.75 ppm. The plume was tracked more than 12 miles from the plant, at which point it was about 4 miles wide (see Figure 4-A).

Low-level inversions are eventually destroyed by the sun's warmth or by a change in the weather. If the inversion is trapping or confining a plume, the plume is mixed to the ground while the inversion is breaking up or being destroyed. The process, called a "fumigation" by air pollution specialists, frequently causes very high contamination at ground level for 30 minutes to an hour. Using the data collected north of Union Carbide plant and depicted in Figure 5, it was calculated that a ground-level concentration of 0.33 ppm SO_2 was likely to have occurred when the inversion was destroyed. The fumigation would have taken place in an area about 3 miles wide and from U.S. 50 north to the vicinity of Dam No. 2 on the Muskingum River. The area where the plume was intersecting the surface and later was likely to have fumigated coincides with an area of maximum sulfation rate found in April and May, 1969, and shown in Figures 2 and 3.

January 11, 1969

This day was a typical winter day in the Upper Ohio River Valley. A broken cloud deck persisted at 2500 to 3000 feet. The atmospheric stability was neutral to the height of the cloud bases. The winds were generally about 7 miles per hour near the surface and increased to about 10 miles per hour at the base of the clouds. A marked veering of the wind direction with height occurred. Near the ground the winds were from the southwest. They turned steadily in a clockwise direction with elevation and at 1700 feet above the ground were west-northwest (Table 3).

An aerial survey of the distribution of sulfur dioxide and particulate matter was made from 1000 to 1200 hours. The horizontal distribution of contaminants was determined by following Interstate I-77 between Wood County Airport and Caldwell, Route 76 between Beverly and Smith's Chapel Cemetary, the power lines to the east and northeast of Beverly and radials from the OMNI navigational beacon located 6 miles north of Waverly.

Significant findings were:

1. The plumes from Union Carbide and the Beverly Power Plant intersected in an area northeast of Marietta. Each plume could be identified on the traverses along I-77, but they were not identifiable as separate plumes east of the highway (see Figure 6).

2. The combined plumes were detected over the Ohio River between St. Marys and Sistersville. This area is more than 17 miles from the Union Carbide plant and more than 28 miles from the Beverly Power Plant.

3. Along I-77, the Union Carbide plume contained an average of 480,000 5-micron or larger particles per cubic foot. The Beverly Power Plant plume contained an average of 340,000 particles per cubic foot. Outside the area subjected to the discrete plumes, the concentrations were 80,000 particles per cubic foot near Caldwell and 135,000 particles per cubic foot near the Wood County Airport. The concentration of particles in the plumes was from 3 to 6 times greater than outside the plumes.

4. The edges of the plume were easily and simultaneously detected on the SO_2 and particle sensors. When particle concentrations exceeded 75,000 to 80,000 particles per cubic foot, SO_2 concentrations exceeded the minimum detectable level. (For purposes of these analyses, 0.05 ppm was considered to be the minimum detectable level for SO_2.)

5. The horizontal dimension of the plume greatly exceeded the vertical dimension. Cross sections labeled A-A' and B-B' have equal vertical and horizontal

Table 3. WINDS ALOFT FROM PILOT BALLOON OBSERVATIONS MADE AT STEWART AIR PARK ON JANUARY 11, 1969

Height, ft	Time (EST)											
	0900		1000		1030		1100		1130		1200	
	Direction, degrees	Speed, mph	Direction, degrees	Speed, mph	Direction, degrees	Speed, mph	Direction, degrees	Speed, mph	Direction, degrees	Speed, mph	Direction, degrees	Speed, mph
150	250	7	235	6	235	7	230	7	260	9	230	4
500	240	9	235	5	240	7	230	6	255	7	225	3
800	240	8	250	5	260	7	255	4	255	8	250	3
1,100	250	10	260	5	260	6	270	6	255	6	255	5
1,400	295	8	290	7	265	7	275	8	250	4	-	-
1,700	290	6	300	8	300	9	300	7	280	7	-	-
2,000	280	8	280	7	285	8	285	6	260	8	-	-

Figure 6. Plan and elevations of plumes measured on January 11, 1969, during surface and aerial traversals. (Contours of SO_2 given in parts per million.)

scales. The contaminants are generally confined to within 2000 feet of the surface. Detailed representations of the plumes along I-77 (Figure 7) in which the horizontal scale is 1/10 the vertical scale shows that the plume from the Beverly plant was confined to the lower 2500 feet and the plume from Union Carbide extended about 1500 feet above the surface. These differences are attributed to the higher stacks at Beverly and to the greater distance that the Beverly plume had traveled at the point where the sampling was performed.

6. A mobile sampler installed in a vehicle cruised I-77 as the aircraft sampled above. The ground-level data correlated very well with the airborne data. Short-period ground-level SO_2 concentrations reached 0.3 ppm.

7. Most of the particles had an equivalent diameter of less than 1.0 micron. Several observations of particle size were made. The ratio of the number of particles greater than 1.0 micron to particles between 0.5 and 1.0 micron varied from 1:3 to 1:5. In other words, the plumes contained 3 to 5 times more particles with diameter of 0.5 to 1.0 micron than particles with diameter greater than 1.0 micron. This may be particularly significant because the most numerous particles are in the range wherein deposition in the respiratory system is reasonably effective (55 to 80% are deposited in the respiratory

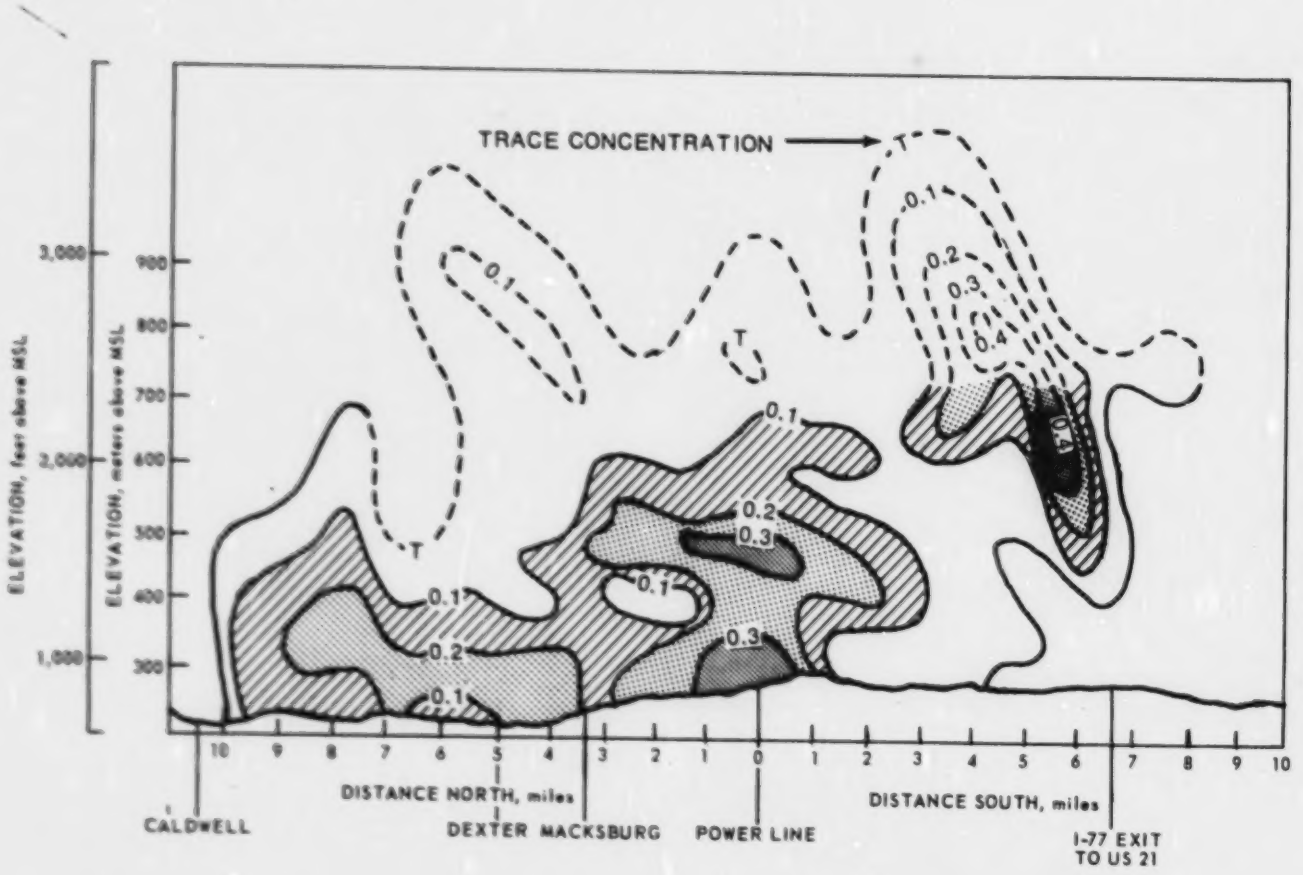

Figure 7. Vertical cross section (along I-77) of plume from Beverly Power Plant; approximately 13 miles downwind from plant. Aircraft traverses at 1300, 1850, 1900 and 2400 feet MSL; 2 automobile traverses on I-77. All data taken between 0900 and 1200 EST January 11, 1969. Isopleths in parts per million projected above flight level shown as dashed lines.

system)[5] and also in a range that impairs visibility.[6]

In summary, the sampled data for sulfur compounds and particulates show:

1. Widespread contamination from two major sources of sulfur compounds, including sulfur dioxide, was observed.

2. Interstate transport of pollutants was common.

3. High short-term SO_2 contamination was found in the same areas that had maximum monthly sulfation rates.

4. Sulfur dioxide and particulate contamination coincided. Where SO_2 was found, particulate concentrations were greatest. Where SO_2 was not detected, particulate concentrations were lowest.

IV. SURVEY OF AIR POLLUTION DAMAGE TO VEGETATION

Plants are sensitive tools by which the presence of several airborne toxicants in low concentration can be detected and evaluated. It has been demonstrated that damage to native plants and agricultural crops is an indicator of the presence, distribution, and level of air pollutants in an area.[7,8] Studying the tissue of specific plant species helps to identify toxicants and to estimate their relative concentration in the atmosphere. In many cases, chemical analysis of foliage is also helpful.[9]

To determine whether present ambient levels of air pollutants in the Parkersburg, West Virginia - Marietta, Ohio, area damaged indigenous vegetation, two field inspections were made during the 1969 growing season.

Extensive damage by chlorine was found on plants growing in the vicinity of the Amax plant near Washington, West Virginia. Injury by fluoride was detected on vegetation near the Johns-Manville Fiber Glass plant in Vienna, West Virginia. Sulfur dioxide injury had developed on indigenous plants located northeast and southeast of the Union Carbide plant in River View, Ohio. Locations of damage to indigenous vegetation are shown in Figure 8.

CHLORINE DAMAGE

Chlorine has a lower phytotoxicant threshold than sulfur dioxide. The concentration of chlorine required for plant damage is less than that reported for sulfur dioxide.[10] At Boyce-Thompson Institute, Zimmerman[11] exposed various plants to chlorine at concentrations of 0.46 to 4.67 ppm. Sixteen species out of 19 were susceptible to leaf injury from those concentrations. Brennan et al.[10] reported that alfalfa and radish foliage was injured from 2-hour exposure to 0.1 ppm of chlorine.

Brennan et al. exposed tomato plants to three different Cl_2 levels for 2- and 3-hour periods. Half the plants were sprayed periodically with water, and half were left unsprayed. Response of the plants whether wet or dry was similar. It was found that a concentration of 0.31 ppm caused no damage, 0.61 ppm slight injury and 1.38 ppm severe damage.

High chlorine concentrations cause acute injury similar in pattern to that caused by sulfur dioxide or similar to that caused by fluoride when the outer leaves

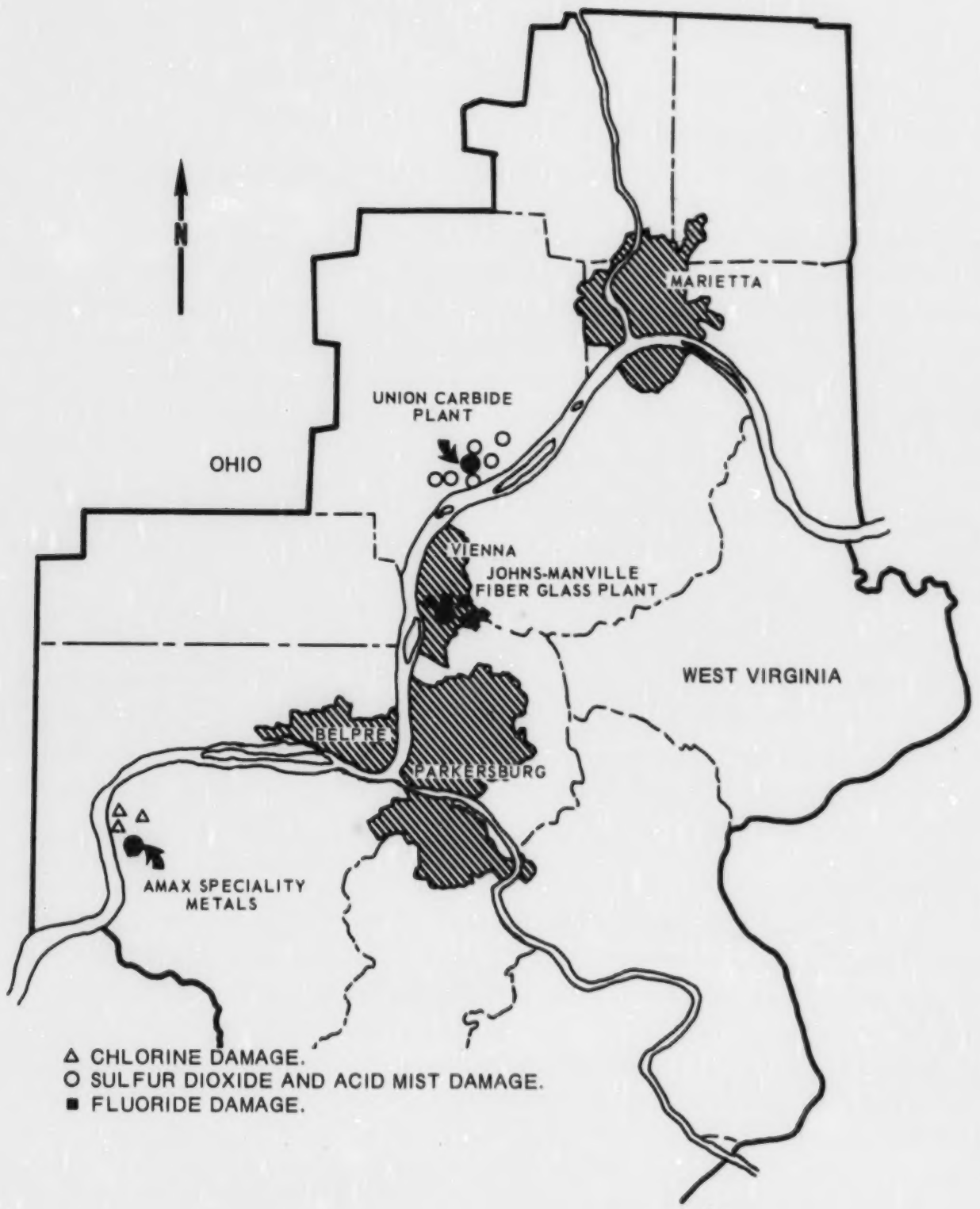

Figure 8. Locations of damage on indigenous vegetation.

are injured at their margins. In some instances, only scattered brown spots occur over the leaf. In 1968 Hindawi[9] reported leaf drop in privet hedges following an exposure to chlorine. In 1951 Schmidt[12] reported defoliation following chlorine fumigation of peach, apple, apricot, and quince trees.

Thornton and Setterstron[13] compared the toxicity of five gases and concluded the relative toxicity to green plants as Cl_2, SO_2, NH_3, H_2S in decreasing order. Zimmerman[14] arrived at a similar conclusion, namely HF, Cl_2, SO_2, NH_3, H_2S. Brennan et al. agree that chlorine is a strongly active phytotoxicant.

On June 6, 1969, chlorine damage was found on wheat and corn grown in fields northeast and adjacent to the Amax plant. Tops of the leaves were bleached and the plants looked whitish or light green in color. About one-half mile northwest of the plant, pear, apple, and maple trees had been damaged by chlorine. The leaves showed yellowing, spotting, and margin injury. The leaves of the maple had dropped prematurely. Table 4 lists chlorine damage observed on plants.

Table 4. CHLORINE INJURY FOUND ON INDIGENOUS VEGETATION IN WASHINGTON, WEST VIRGINIA

Date	Location	Plant varieties	Pollutants	Degree of damage[a]
6/6/69	1/2 mile northwest of Amax plant	Apple	Chlorine	Extensive
		Pear	Chlorine	Extensive
		Maple	Chlorine	Extensive
	1/2 mile northeast of Amax plant	Wheat	Chlorine and acid mist, probably hydrochloric acid	Severe
		Corn	Chlorine and acid mist	Severe
		Mullein (weed)	Chlorine	Extensive
8/14/69	Moellendick farm, about 3/4 mile northwest of Amax plant	Maple trees	Chlorine	Severe
		Grape vine	Chlorine and acid mist	Moderate
		Gladiolus	Chlorine	Moderate
		Redbud	Chlorine and acid mist	Extensive
		Hybiscus	Chlorine and acid mist	Extensive
		Lilac	Chlorine	Moderate
		Corn	Chlorine	Extensive
8/14/69	1/2 mile northwest of Amax plant	Apple	Chlorine	Severe
		Pear	Chlorine	Severe
		Maple	Chlorine	Severe

[a]Moderate - indicates 5 to 25 percent of leaf area injured.
Extensive - indicates 25 to 50 percent of leaf area injured.
Severe - indicates greater than 50 percent area injured.

On August 14, 1969, severe chlorine damage was found on vegetation at the Moellendick farm 3/4 mile northwest of Amax. Severe damage was evident on apple trees, grape vine, gladiolus, redbud, lilac, corn and hybiscus. Injury of broad leaf plants was brown-orange on the margin of the leaf tissue and necrotic spots had formed on the surface of leaves. Injury similar to that for SO_2 was observed on grape leaves, redbud, apple, and hybiscus. Both middle age and old leaves are most readily injured by chlorine. Defoliation was observed on injured maple and

apple trees. Ambient chlorine levels measured in the area of the damaged trees (reported in Table 10, Section V) were found to be high enough to cause severe damage to vegetation. Vegetation growing in the adjacent Ohio area across the Ohio River were inspected, but did not appear to be similarly affected by chlorine at that time.

SULFUR DIOXIDE DAMAGE

Sulfur oxides can cause both acute and chronic plant injury. The injury is thought to be caused by sulfur dioxide and/or sulfuric acid mist that forms from sulfur trioxide. Under humid environmental conditions, SO_3 rapidly hydrates, forming small airborne droplets of sulfuric acid mist. The presence of dew or mist on the surface of the leaf also enable the SO_2 to be dissolved and accumulated as a droplet of acid that causes injury to the leaf.

Sulfur dioxide enters the leaf tissue through the stoma, and the gas reacts with water to produce the sulfite ion, which can be slowly oxidized to the sulfate ion.[15] Both the sulfate and sulfite ions are toxic to plant cells when present in excessive amounts.

The accumulation of sulfite in the tissue of the leaves produces two types of injury, chronic and acute, depending upon the rate of accumulation. The markings produced on broad leaf foliage consist primarily of regular necrotic or dead areas between the veins. The color of the markings is usually white or ivory, although with some species they may be dark brown or reddish-brown. The markings that develop on narrow leaves occur as necrotic streaks developing near the tip and extending downward to the base of the leaf. With pine needles the marking usually begins at the tip and extends toward the base. Middle-aged leaves are more sensitive to SO_2 than the young and old leaves. Exposure of plants to sublethal concentrations of SO_2 for several days or weeks could cause the development of the gradual yellowing or chlorotic symptom of chronic injury.[16]

On June 6, 1969, typical damage by SO_2 was observed on indigenous vegetation northeast and southwest of the Union Carbide plant. Sulfur dioxide injury was detected on black mustard and common foxtail grass about 0.5 mile northeast of the plant, at the Union Carbide Park and on grape vines and pine trees growing at the Ralf Doak residence located on County Road 10 and 7 southwest of Union Carbide. Damage by SO_2 was also found on apple, peach, plum, and raspberry leaves.

August 14, 1969, injury by SO_2 was found on the leaves of tomato, peach, grape vine, and apple trees grown at the Ralf Doak residence. Pine trees about 1.5 miles

south of Union Carbide also developed severe damage from SO_2. Table 5 shows damage from SO_2 on indigenous vegetation grown at various locations.

Table 5. SULFUR DIOXIDE INJURY FOUND ON INDIGENOUS VEGETATION AT VARIOUS LOCATIONS IN SURVEY AREA

Date	Location	Plant varieties	Pollutants	Degree of damage
6/5/69	Northeast of Union Carbide plant, about 1/2 mile	Black mustard	SO_2	Extensive
		Grass (Common foxtail)	SO_2	Extensive
	Union Carbide Park (Bakelite Park), north of plant	Grape vine	SO_2	Moderate
		Evergreen	SO_2	Moderate
	Southwest of Union Carbide plant at the Ralf Doak residence on County Road 10 and 7.	Apple	SO_2	Severe
		Peach	SO_2	Extensive
		Plum	SO_2	Extensive
		Raspberry	SO_2	Severe
		Grape	SO_2	Severe
6/6/69	3/4 mile south of E. I. du Pont plant	Rose	Acid mist	Moderate
		Evergreen	Acid mist	Moderate
	Northeast Amax plant, between Amax plant and Marbon Chemical plant	Maple	Acid mist	Severe
8/14/69	Southwest of Union Carbide plant at the Ralf Doak residence on County Road 10 and 7	Tomato	SO_2	Moderate
		Peach	SO_2	Severe
		Grape vine	SO_2	Moderate
		Apple	SO_2	Extensive
	South of Union Carbide plant about 1-1/2 miles	Pine trees	SO_2	Severe

FLUORIDE DAMAGE

Gaseous hydrogen fluoride is toxic to some plants in concentrations as low as 0.1 parts per billion.[15] Soluble particulate, as well as gaseous fluorides, may accumulate outside or inside the leaf and cause leaf injury. Fluoride is absorbed throughout the whole leaf blade and causes a burn.

Citrus trees exposed continuously to low levels of fluoride for many months develop leaf chlorosis, produce smaller leaves, bear less fruit, and grow less vigorously than comparable trees exposed to fluoride-free air.[7] Fluoride was found by Brewer et al.[17] to cause chlorosis, dwarfing, and abcission of leaves, dropping of fruits, and lower yield.

Plants containing enough fluoride to show evidence of damage can cause injury to livestock and even to human beings who consume sufficient quantities of

contaminated plants.[18,19] Information reported in the March 1967 technical report and presented at the conference showed up to 700 ppm fluoride in the maple trees near the Johns-Manville Fiber Glass plant at Vienna, West Virginia.

On June 5 and 6 and August 14, 1969, the area in the vicinity of the plant was inspected again. Tip damage and margin burn by fluoride was found on apple, dogwood, peach, and maple trees, at locations listed in Table 6 and shown in Figure 8.

Table 6. FLUORIDE INJURY ON INDIGENOUS VEGETATION IN VIENNA, WEST VIRGINIA

Date	Location	Plant varieties	Degree of damage
6/6/69	G. T. Coes residence on Ninth Street, north of Johns-Mansville Fiber Glass Plant	Apple	Severe
		Strawberry	Severe
		Peach	Extensive
		Dogwood	Extensive
		Evergreen (arbavita)	Extensive
		Roses	Severe
		Peonies	Severe
		Maple	Severe
8/14/69		Maple	Severe
		Dogwood	Extensive
		Apple	Moderate
		Peach	Moderate
		Tomato	Little
		Bean	Little

Chemical analysis of the leaf tissue collected from injured vegetation indicated that current fluoride accumulation greatly exceeded the level that would cause severe damage.[20,21,22] Table 7 gives the time, location, plant varieties, and concentration of fluoride in plant tissues. The fluoride concentrations found in the maple leaves in 1969 exceeded fluoride levels found in the same plant variety in 1967.

Chlorine, SO_2, and hydrogen fluoride levels in the Parkersburg, West Virginia - Marietta, Ohio, area are high enough to cause damage to vegetation. During the 1969 survey injury characteristic of each pollutant was identified on indigenous vegetation growing in the general area of sources of the pollutants.

High chlorine concentration caused acute-type injury in the Washington, West Virginia, area with the pattern being similar to that for SO_2 or fluoride when leaves were injured at their outer margins. Defoliation of plants in the area was also caused by the high levels of chlorine.

Table 7. FLUORIDE ANALYSIS OF INJURED VEGETATION FOUND IN 1969 IN VIENNA, WEST VIRGINIA
(micrograms F/g)

Leaf specimens	Parts of leaf analyzed	Concentration
Apple	Whole leaf	60
Dogwood	Tips and margins	1,000
Dogwood	Midportions	510
Peony	Tips and margins	560
Peony	Midportions	350
Maple	Tips and margins	960
Maple	Midportions	420
Peach	Tips and margins	340
Peach	Midportions	210
Reagent blank		8

These results should be considered as having no significance closer than ± 10 micrograms F/g.

Severe plant damage from SO_2 and/or acid mist formed by conversion of SO_2 to SO_3 and then to sulfuric acid was found on plant varieties growing in the vicinity of the Union Carbide Power Plant at River View, Ohio. The sulfur dioxide caused irregular necrotic or dead areas between the veins.

The extent of fluoride damage on vegetation in Vienna, West Virginia, north of the Johns-Manville Fiber Glass plant was comparable to that observed in 1967. Measured fluoride content of leaf specimens from the same plant varieties collected and analyzed in 1967 shows equivalent or even higher accumulation of fluorides.

V. INVESTIGATION OF ODOR AND EYE IRRITATION

On April 30, 1968, officials of the Ohio Department of Health and the West Virginia Air Pollution Control Commission received copies of petitions bearing the names of over 800 residents in the Little Hocking - Porterfield, Ohio, area requesting an investigation of the air pollution problems in this area of the Ohio River Valley. The area affected by air contaminants is situated across the Ohio River from the Washington Bottom industrial complex in West Virginia.

A letter accompaning the petition from a representative of the Little Hocking Community Club, cited offensive odors and irritant pollutants from chemical plants as the cause of coughing, watering eyes, and difficulty in breathing frequently experienced by the Ohio residents.

Complaints of odor and eye and nose irritation also had been received over a period of time from West Virginia residents in Washington, West Virginia, by the Wood County Health Department and West Virginia Air Pollution Control Commission. Incidents of eye burning and throat discomfort, sometimes accompanied by odors, was consistently mentioned in these reports.

In 1968 the West Virginia Air Pollution Control Commission established and operated a network of air samplers and wind sensors in the Washington Bottom area in an attempt to evaluate the problem and to identify the sources of the odors and irritant pollutants. Measurements of oxidants and other commonly sampled pollutants at these sites could not be successfully correlated with incidents of eye irritation (lachrymation), suggesting the problem was one of a more chemically complex nature.

At the consultation meeting on December 17, 1968, representatives of West Virginia Air Pollution Control Commission, Ohio Air Pollution Control Board, and NAPCA formulated plans for a 4- to 6-month joint investigation of the reported problem. Basically, the state agencies were to establish or continue operating existing sampling stations in the Lubeck district in West Virginia and Belpre Township in Ohio to form an area-wide sampling network for suspended particulates, dustfall, and sulfation. Wind measurements taken at sampling stations operated by West Virginia would be used in the evaluation of sampling results.

Investigation to be conducted by NAPCA consisted of an on-site odor and irritant survey and an evaluation of potential emissions of known or suspected lachrymators and odorous materials from industrial plants in the area.

ODOR AND IRRITANT SURVEY

The odor and irritant survey was conducted from June 24, 1969, through July 3, 1969, in the general area where complaints had been reported.

The objective of the survey was to identify the presence, types, frequency, and intensity of odors and sensory irritants, the possible sources of these odors and irritants, and the areas affected. Emphasis was placed on the documentation of odor or irritant incidents and the identification of their source. Air samples were collected when practical and pertinent to the identification of the odor or irritant experienced.

Seventeen odor and irritant observations were conducted during the survey period in the area shown in Figure 9. Patrols were conducted during various times of the day and night and lasted from 1-1/2 to 4 hours depending upon the number and types of observations made during each patrol. The observations were made from an open automobile. Each patrol started at Washington School in Washington, West Virginia. The route followed was: (1) east on DuPont Road with excursions on side roads heading to the River; (2) east on West Virginia Route 2 into Parkersburg; (3) across the bridge into Belpre, Ohio; (4) west on U. S. 50 and Ohio Route 7 to Little Hocking, Ohio, with excursions on the side roads along the river. When an investigator traversed an odorous area, he would determine the odor quality, the presence of eye and respiratory irritants, and wind direction and speed.

Air sampling equipment powered by a gasoline-engine generator was set up in the back of a station wagon. Since chlorine was the predominant odor, atmospheric samples were collected and analyzed for chlorine. Static samples were obtained by use of alkaline plates that were fastened to telephone poles located at 19 stations throughout the area. Methods used to measure chlorine, odor, and wind speed and direction are summarized in Table 8.

There are five major industrial plants located in the area: E. I. Du Pont, Marbon Chemical, Amax, Burdett Oxygen, and Shell Chemical. Shell Chemical is located in Belpre, Ohio, and the other four are located in the Washington Bottom area in West Virginia. These plants are all located on the lower flood plain on the river within 3-1/2 miles of each other (Figure 9).

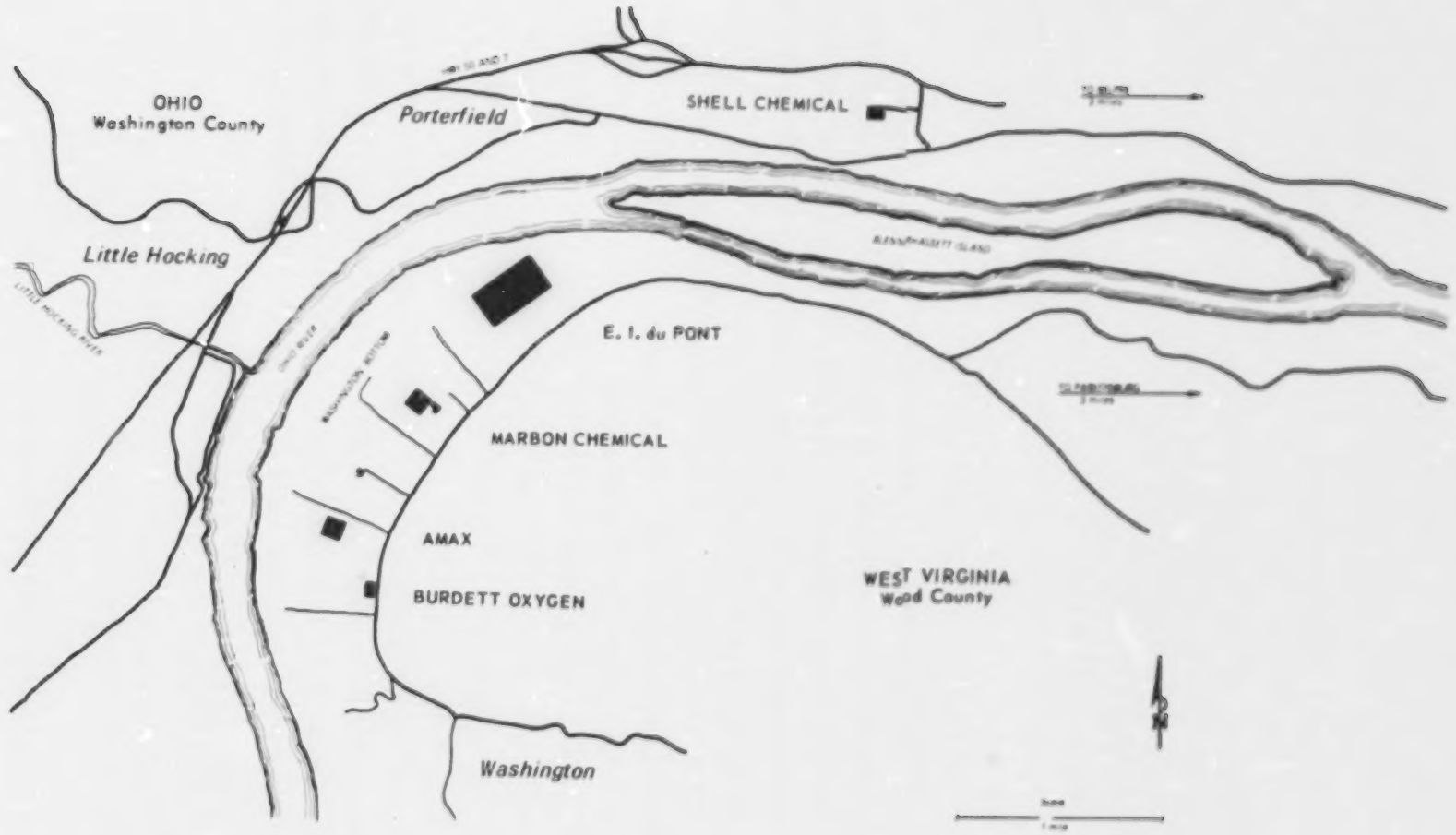

Figure 9. Odor and irritant survey area.

Table 8. SUMMARY OF MEASUREMENT METHODS

No.	Pollutant or parameter	Sampling device	Analytical method
1	Chlorine	Mast oxidant meter[a]	Coulometric
2		MSA detector tube	Colorimetric
3		Na_2AsO_2 solution[b] in impingers	Colorimetric[c]
4		Alkaline plate[d]	Colorimetric
5	Odor and irritants	Nose, mucous membranes	Olfactory perception, eye or respiratory irritation
6	Wind speed	Propeller-type anemometer	Mechanical rotation
7	Wind direction	Helium-filled balloons	Tracking with a compass

[a]Calibrated with chlorine gas.

[b]Laboratory method, Division of Abatement, NAPCA.

[c]American Society for Testing Materials, 1965. Book of ASTM Standards, Part. 23, pp. 21-28.

[d]Waller, Margaret A. and Norman A. Huey, "Evaluation of a Static Monitor of the Atmospheric Activity of Sulfur Oxides, Nitrogen Dioxide, and Chloride." Presented at the 62nd Annual Meeting of APCA, June 22-26, 1969.

Odor quality of materials emitted by each of these plants was established by field investigators who stood immediately downwind from each plant and noted its characteristic odorant emission. This was done under various wind conditions including those in which no other plant was located further upwind.

In this manner odorant emissions from Amax, Shell Chemical, E. I. du Pont, and Marbon Chemical were classified as chlorine, oil refinery, and "plastics," Odorant emissions from E. I. du Pont and Marbon Chemical could not be distinguished by the field investigators, and emissions from both plants are classified as having a plastics odor. There were no odorant emissions detected from Burdett Oxygen.

The number of odor incidents observed during this survey are summarized in Table 9. Chlorine odor constituted 32 of the 53 odor incidents observed. Because five of these incidents were observed in Ohio, interstate transport of odor pollution is indicated. There were also three cases observed of interstate transport of plastics odor.

Table 9. NUMBER OF POSITIVE ODOR OBSERVATIONS

Type of odor	State of origin	Location of odor observation		Total
		Ohio	West Virginia	
Chlorine	West Virginia	5	27	32
Plastics	West Virginia	3	11	14
Oil refinery	Ohio	7	0	7

Data obtained during the survey on odor, eye and respiratory irritation, wind speed and direction, and chlorine concentration are shown in Table 10. There were five cases of respiratory irritation and one case of eye irritation associated with chlorine odor. There was one incident of eye irritation with no recognizable accompaning odor. This case of eye irritation was experienced throughout the Washington Bottom area and persisted for about 1 hour. Winds were calm during this period of time.

In cases when the Mast oxidant meter recorded chlorine values of greater than 1.8 ppm (off scale), the MSA detector tube and Na_2AsO_2 methods were used to confirm these results and to obtain measurable values. During these incidents chlorine values obtained by the detector tube method were 25 to 100 ppm, and values obtained by the Na_2AsO_2 method were 34 and 69 ppm. A number 2 odor strength, as determined by a Scentometer, was obtained during observation number 28 and an odor strength of number 1 was obtained during observation numbers 16 and 29.[23] Odor strengths of less than 1 were obtained at all other times that observations were made. These high chlorine episodes (>25 ppm) were associated with emissions of dense white smoke from Amax. During the episode when 100 ppm was measured, the investigators experienced severe eye and throat irritation, nausea, and headache and were unable to continue with the survey. The American Conference of Governmental Industrial Hygienists threshold limit value for chlorine is 1 ppm.[24]

The odor threshold concentration of chlorine is 0.3 ppm.[25] In certain cases the odor of chlorine was observed when the atmospheric chlorine concentration was below this value. The odor threshold concentration indicated above was determined for the pure gas; however, under field conditions, chlorine reacts with moisture and other materials to form compounds that may have lower odor thresholds than pure chlorine but the same odor quality as chlorine.

The odors observed in relation to wind direction and source of odor emission are mapped in Figures 10 to 15. In all cases of observed odors, the observer was positioned downwind from the source of emission that was associated with the characteristic odor. In cases of interstate pollution, wind conditions were conducive to transport of odorants emitted from Amax, DuPont, and Marbon to the points where odors were observed. (Figure 10).

Results obtained by exposure of alkaline plates are shown in Table 11. Highest chloridation rate was measured at station No. 6 located on a public road in front of Amax. Chloridation rate is used as a measure of chlorine dosage over the period

Table 19. ODOR AND IRRITANT OBSERVATIONS

Observation number	Date	Hour of day	Location number[a]	Type of odor	Eye irritation present	Respiratory irritation present	Wind direction,[b] degrees	Wind speed,[c] mph	Chlorine concentrations, ppm		
									Mast oxidant meter	MSA detector tube	Impinger using Na_2AsO_2
1	6/24/69	1600	Between 5 and 6	Chlorine	No	No		Calm			
2	6/25/69	1530	Between 5 and 6	Chlorine	No	No	230	5			
3	6/25/69	1550	7	Chlorine	No	Yes	230	5	0.7	< 1	
4	6/25/69	1930	8	Chlorine	No	No	230	5			
5	6/25/69	2100	1/4 mile west of 19	Chlorine	No	No	180	5	< 0.1		
6	6/25/69	2115	19	Chlorine	No	No	180	5			
7	6/26/69	1030	Between 5 and 6	Chlorine	No	Yes	240	5	0.8	< 1	
8	6/26/69	1130	Highway 50 and 7 in front of Shell Chemical	Oil refinery	No	No	240	5			
9	6/26/69	1400	Between 5 and 6	Chlorine	No	No	210	5		< 1	
10	6/26/69	1415	7	Chlorine	No	No	210	5	< 0.1	< 1	
11	6/26/69	1830	Between 5 and 6	Chlorine	No	No	200	5	< 0.1	< 1	
12	6/26/69	1930	1/4 mile north of 8	Chlorine	No	No	190	5	< 0.1		
13	6/26/69	2000	1/2 mile northeast of 19	Chlorine	No	No	180	5	< 0.1		
14	6/26/69	2025	1/4 mile east of 19	Chlorine	No	No	170	5	< 0.1		
15	6/27/69	740	11	Plastics	No	No		Calm			
16	6/27/69	810	Between 5 and 6	Chlorine	No	Yes		Calm	< 1.8	25	34
17	6/27/69	930	Between 5 and 6	Chlorine	No	No	200	10	0.4	< 1	
18	6/27/69	945	7	Chlorine	No	No	200	5	< 0.1		
19	6/27/69	1000	8	Chlorine	No	No	200	5	< 0.1		
20	6/27/69	1010	10	Plastics	No	No	200	15			
21	6/27/69	1100	Highway 50 and 7 in front of Shell Chemical	Oil refinery	No	No	200	15			
22	6/27/69	1120	2 miles northeast of 18	Plastics	No	No	200	15			
23	6/27/69	1630	Between 5 and 6	Chlorine	No	No	200	15	0.7		
24	6/27/69	1635	7	Chlorine	No	No	200	15			
25	6/27/69	1700	11	Plastics	No	No	200	15			
26	6/27/69	1735	1-1/2 miles northeast of 19	Plastics	No	No	200	15			
27	6/27/69	1740	Highway 50 and 7 in front of Shell Chemical	Oil refinery	No	No	200	15			
28	6/27/69	2105	Between 5 and 6	Chlorine	Yes	Yes	210	8	< 1.8	100	69

Table 10 (continued). ODOR AND IRRITANT OBSERVATIONS

Observation number	Date	Hour of day	Location number[a]	Type of odor	Eye irritation present	Respiratory irritation present	Wind direction,[b] degrees	Wind speed,[c] mph	Chlorine concentrations, ppm		
									Mast oxidant meter	MSA detector tube	Impinger using $Na_2As_2O_2$
29	6/28/69	715	Between 5 and 6	Chlorine	No	Yes	170	5	< 1.8	25	
30	6/28/69	730	7	Chlorine	No	No	170	5	< 0.1	< 1	
31	6/28/69	745	1/4 mile north of 8	Chlorine	No	No	170	5			
32	6/28/69	845	On highway 50 and 7 in Belpre	Oil refinery	No	No	200	5			
33	6/28/69	900	Downtown Belpre	Oil refinery	No	No	200	5			
34	6/28/69	1945	1	Chlorine	No	No	330	5	< 0.1		
35	6/28/69	2000	8	Plastics	No	No	340	5			
36	6/28/69	2030	11 to 12	Plastics	No	No	340	5			
37	6/29/69	600	Between 5 and 6	Chlorine	No	No		Calm			
38	6/29/69	620	2	Plastics	No	No		Calm			
39	6/29/69	630	9	Plastics	No	No		Calm			
40	6/29/69	1900	3	Chlorine	No	No	330	5			
41	6/29/69	1910	10	Plastics	No	No		Calm			
42	6/30/69	610	Between 5 and 6	Chlorine	No	No		Calm	0.8		
43	6/30/69	620	4	Plastics	No	No		Calm			
44	6/30/69	630	8	Plastics	No	No		Calm			
45	6/30/69	1600	Between 5 and 6	Chlorine	No	No	200	10			
46	6/30/69	1620	2 miles northeast of 18	Plastics	No	No	200	10			
47	6/30/69	1630	Highway 50 and 7 next to Shell Chemical	Oil refinery	No	No	200	10			
48	6/30/69	1930	Between 5 and 6	Chlorine	No	No	200	10	0.7	< 1	
49	6/30/69	1940	7	Chlorine	No	No	200	10	< 0.1		
50	6/30/69	2000	Highway 50 and 7 at Shell Chemical	Oil refinery	No	No	180	10			
51	6/30/69	2015	1/4 mile east of 19	Chlorine	No	No	180	10	< 0.1		
52	7/2/69	930-1030	Washington Bottom (general area)	Stinging eye irritation (no odor)	Yes	No		Calm	< 0.1		
53	7/2/69	1030	11	Plastics odor	No	No		Calm	< 0.1		
54	7/2/69	2000	3	Chlorine	No	No	330	5	< 0.1		

[a]Refer to Station Number in Table 11.

[b]Accuracy of measurement is ± 10 degrees. Wind direction was not measured at a calm wind condition.

[c]Measured to the nearest 5 mph. Calm indicates wind speeds less than 5 mph.

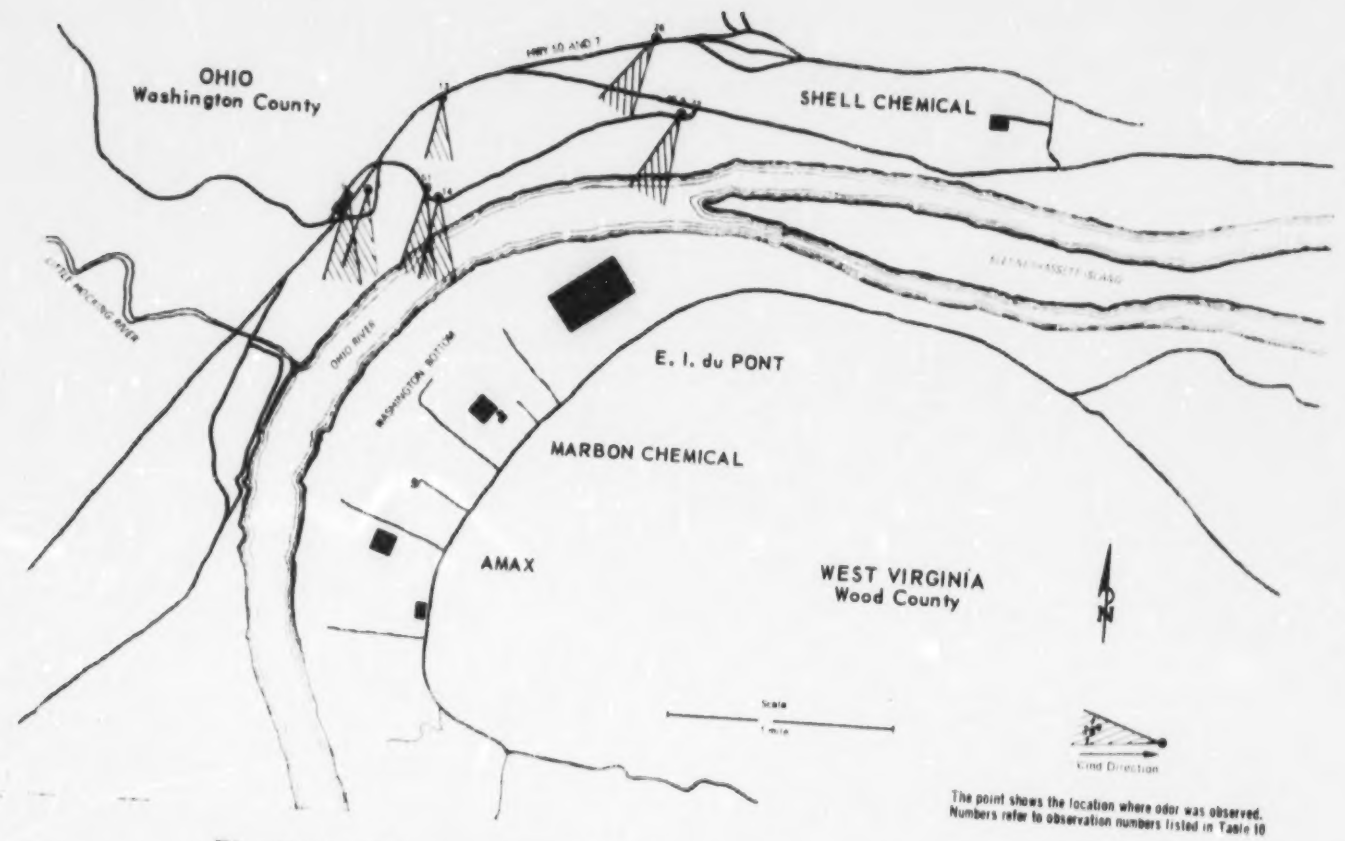

Figure 10. Odor observations showing interstate transport of pollutants.

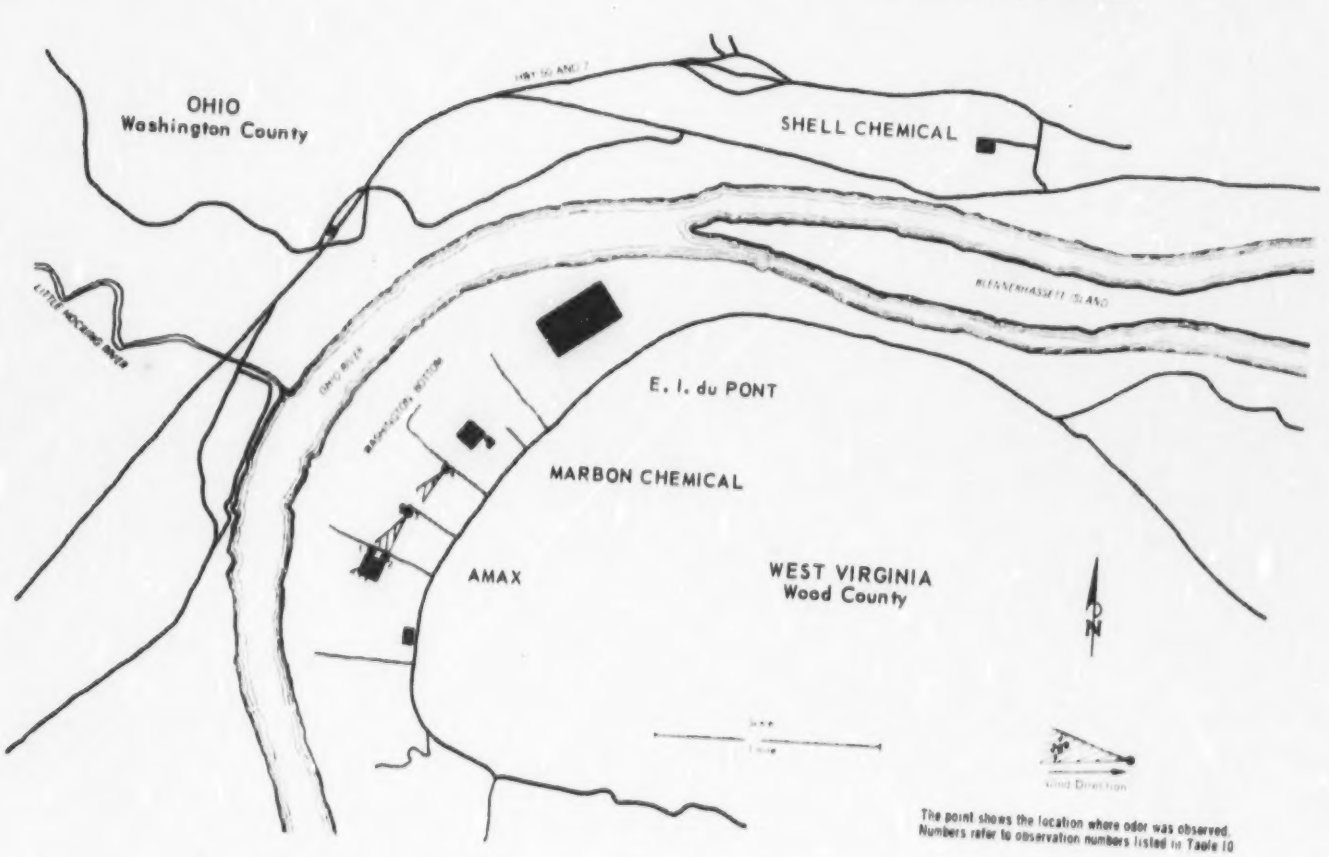

Figure 11. Intrastate odor observations 6-24-69 and 6-25-69.

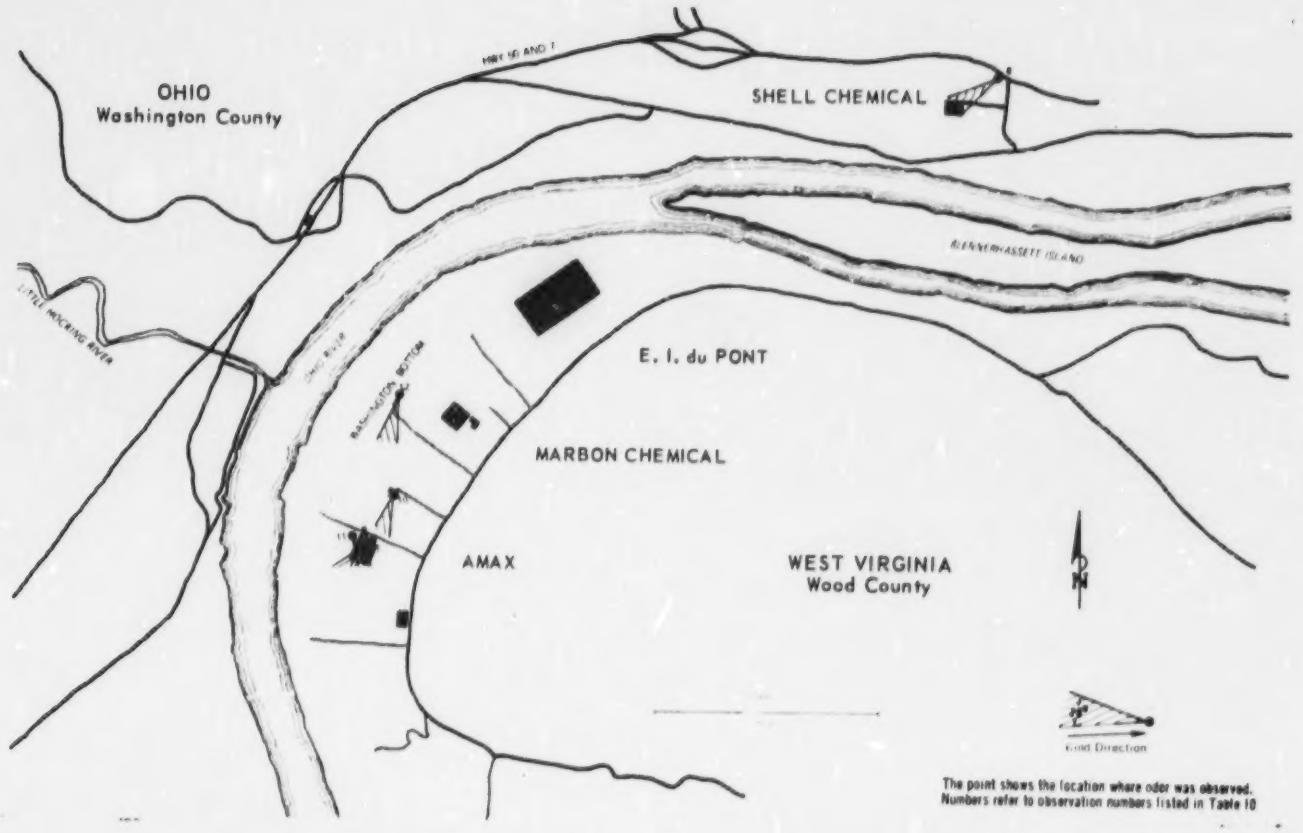

Figure 12. Intrastate odor observations 6-26-19.

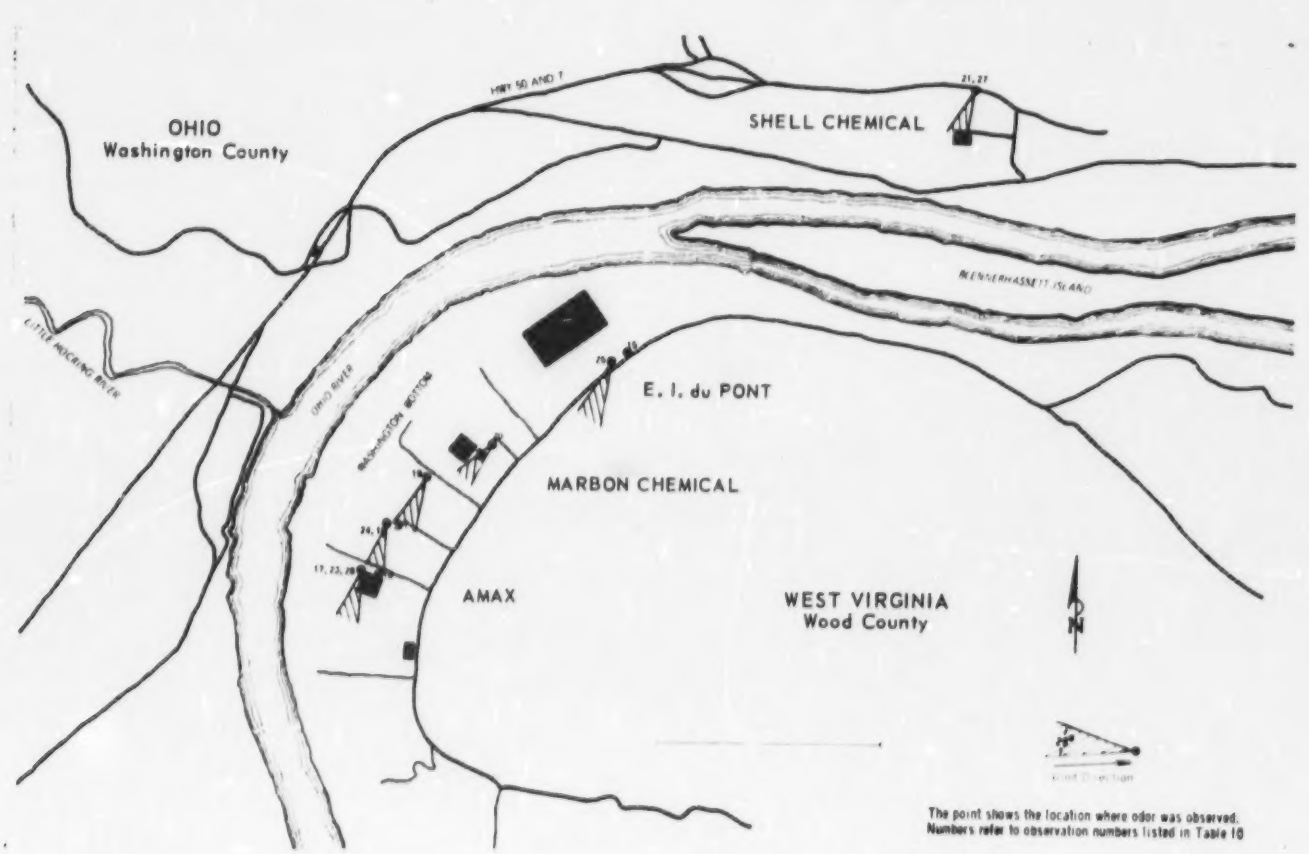

Figure 13. Intrastate odor observations 6-27-69.

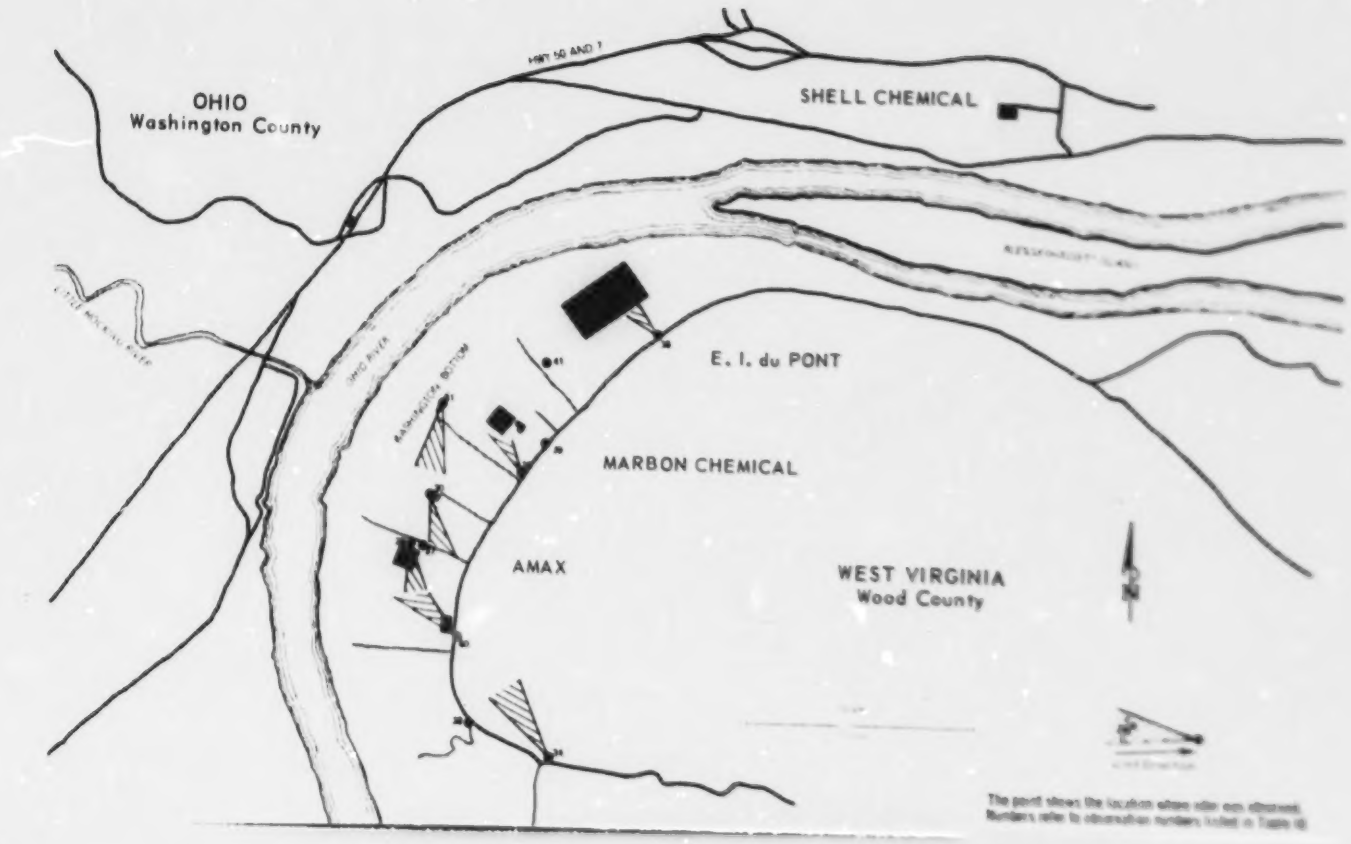

Figure 14. Intrastate odor observations 6-28-69 and 6-29-69.

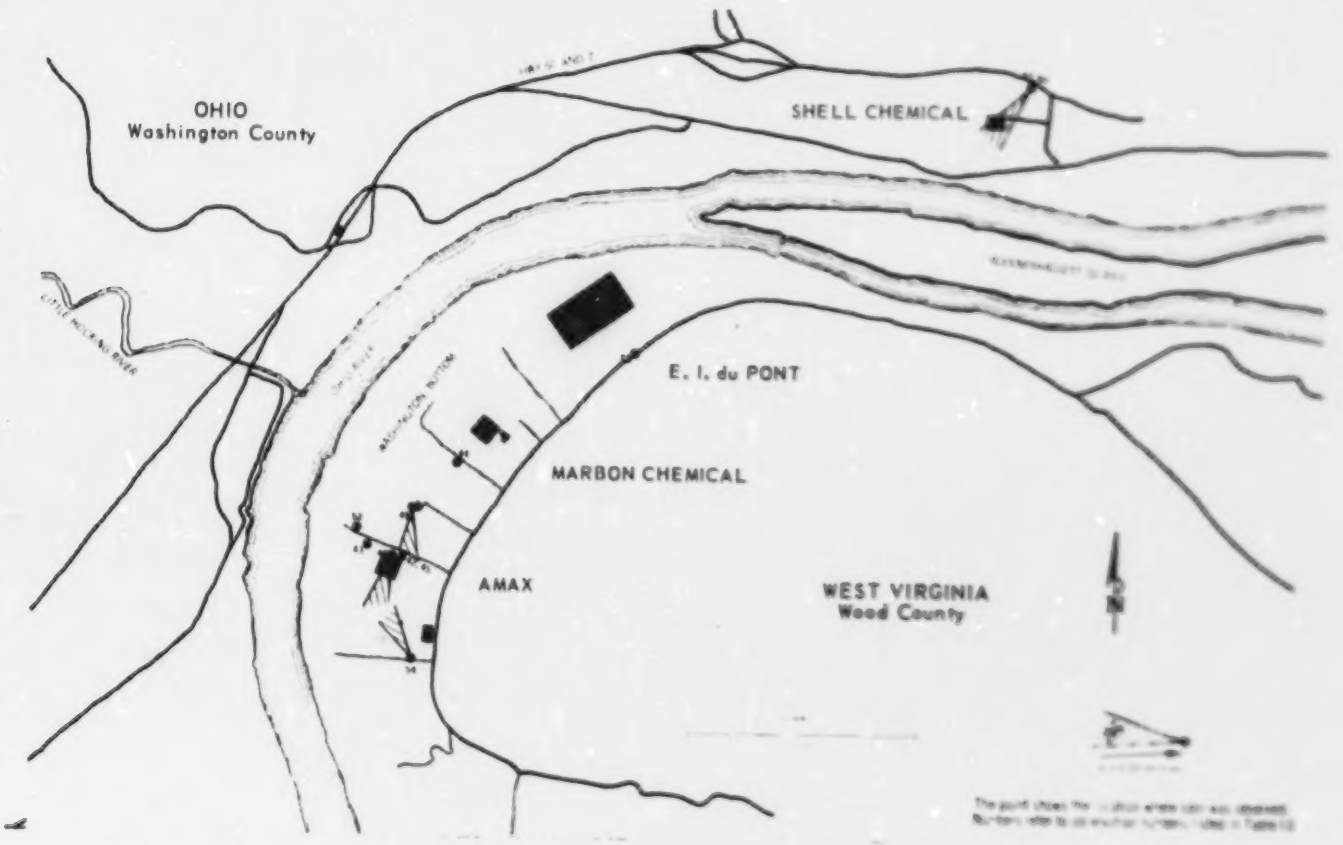

Figure 15. Intrastate odor observations 6-30-69 and 7-1-69 and 7-2-69.

Table 11. RESULTS OF ALKALINE PLATE MEASUREMENTS, 6/24/69 - 7/3/69

Station number	Location	Chloridation rate, μg/cm^2-day
1	Washington School, West Virginia	Vandalized
2	Residential area 1 mile south of Amax	0.6
3	Farm, 1/3 mile south of Amax	0.8
4	Public access road 1/4 mile west of Amax	1.4
5	Amax parking lot	13.6
6	Public access road in front of Amax	46.1
7	Moellendick farm 1/4 mile northeast of Amax	9.2
8	Farm, 1/4 mile southwest of Marbon Chemical	2.4
9	Between Marbon Chemical and Parkersburg Industrial Warehouse	1.2
10	Trailer camp between DuPont and Marbon Chemical	1.1
11	In front of DuPont on DuPont Road	0.9
12	1/4 mile east of DuPont	0.6
13	1/2 mile northeast of DuPont	1.1
14	1-2/3 miles east of DuPont	0.7
15	Corner DuPont Road and River Hill Road	0.8
16	1/2 mile southwest of Little Hocking, Ohio	0.5
17	1/4 mile southwest of Little Hocking, Ohio	0.7
18	Little Hocking, Ohio	0.7
19	3/4 mile northeast of Little Hocking, Ohio	0.4

of exposure. Geographic distribution of chlorine dosage is shown in Figure 16. The area of highest chlorine dosage is located around Amax. The area of next highest chlorine dosage is an elliptical area stretching northeasterly from Amax. The shape of this area was mainly governed by the prevailing wind direction in relation to the source of emission.

EVALUATION OF PROBLEM

In May 1967 the Amax Specialty Metals Corporation resumed production of zirconium and hafnium in the plant bought from the Carborundum Metals Climax Corporation. The plant located in the Washington Bottom area began operation at an accelerated rate to meet the increased demand for these metals. Complaints about odor and eye irritants by residents in this area began after Amax resumed production.

The metal refining operations employed by Amax are highly complex, chemical, batch-type processes emitting various pollutants. Characteristic for batch-type operations, pollutant emissions tend to peak for short time intervals and may overload the air pollution control equipment. Evidence of intermittent intense pollution occurred recently when NAPCA personnel were monitoring chlorine on a public access road near the Amax plant. NAPCA personnel found 70 to 100 parts per million of chlorine; they became ill after a short-term exposure to this high concentration and were forced to leave the area.

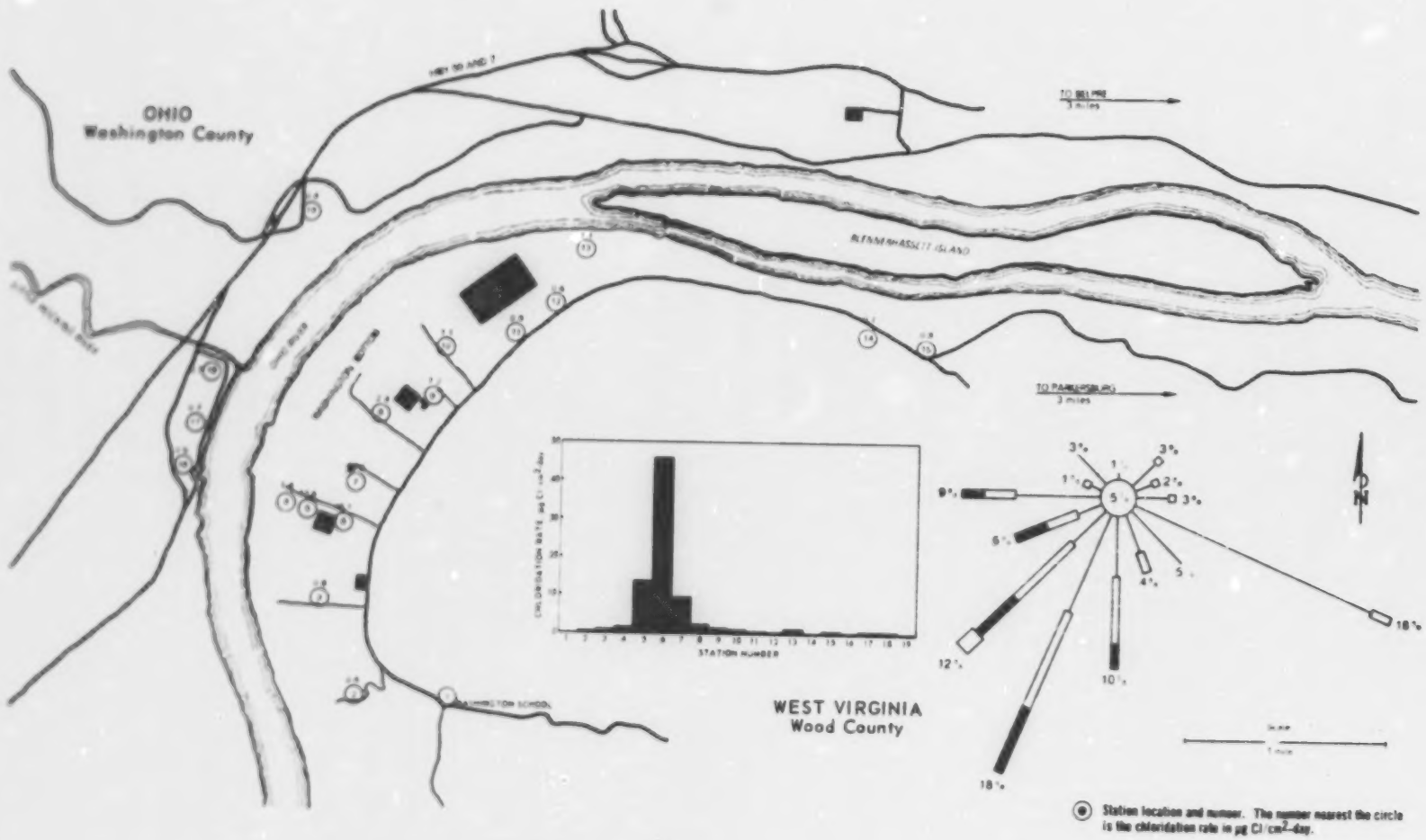

Figure 16. Alkaline plate network 6-25-69 to 7-2-69.

Chlorine emissions from the plant can cause lachrymation in the study area either by themselves or in combination with styrene from nearby chemical plants. Exposure to concentrations of 3 to 6 ppm chlorine causes eye irritation.[26] An even more potent lachrymator is formed when chlorine becomes mixed with styrene.[27] Exposure to concentrations of a few parts per hundred million of combined chlorine and styrene causes intense eye irritation.[28,29]

The Marbon plant, a close neighbor of Amax, emits from its process acrylonitrile and styrene, potential lachrymators by themselves or in combination with chlorine.[30]

The location of the plant and its styrene storage tanks in relation to the Amax plant is shown in Figure 17, an aerial photograph of the Washington Bottom area. Prevailing south-southwest winds in the area frequently carry the effluent from the Amax plant in the direction of the Marbon plant and thereby allow air contaminant emissions from the plants to mix.

The Shell Chemical plant situated five miles upriver from the Amax plant between Porterfield and Belpre, Ohio, emits styrene and toulene, potential lachrymators by themselves or in combination with chlorine.

The E. I. du Pont plant, a close neighbor to Marbon Chemical emits formaldehyde, methylene chloride, and acetic acid, which could create potential odor, lachrymation, and corrosion problems. Gaseous formaldehyde in the 5- to 10-ppm range causes eye irritation and has a definite lachrymator effect.[31]

Process loss information voluntarily furnished to NAPCA by officials of Amax, Marbon Chemical, E. I. du Pont, and Shell Chemical plants have shown emissions of potential lachrymator materials from each plant. Observations taken during the odor and irritant survey by trained observers and descriptions contained in complaint reports by local residents confirm degradation of air quality in the area.

As evidenced from the number of chlorine observations during the brief survey, this pollutant has a pronounced impact on the area. Furthermore, because of the lachrymator potency of combinations of chlorine and styrene at even trace concentrations and the nearness of sources of the two chemicals, it is possible that atmospheric emissions of these materials together contribute significantly to the lachrymation problem of the area.

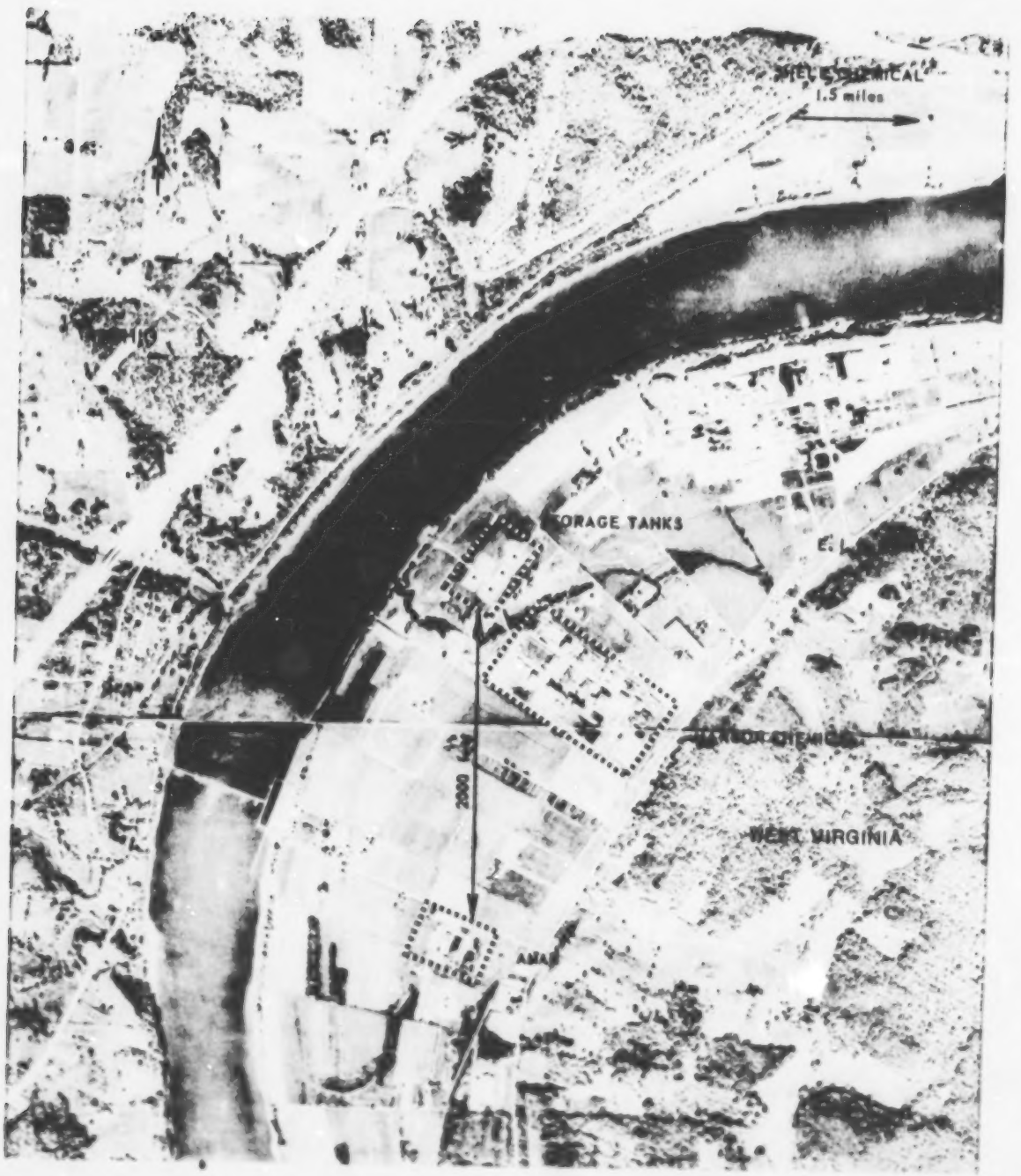

Figure 17. Aerial photograph showing nearness of chlorine (Amax Plant) and styrene (Marbon Chemical Plant) sources.

Control of all atmospheric emissions from the Amax plant to less than a few parts per hundred million chlorine at the company property line would eliminate the potential lachrymator effect from chlorine by itself or in combination with styrene from nearby chemical plants.

Chlorine and hydrochloric acid emissions from chlorinators may be controlled effectively by using a packed-bed scrubber or a floating-bed scrubber with an alkaline scrubbing fluid. Use of a process surge tank to handle peak chlorine emissions from any process surge or upset may allow a more even flow of chlorine to scrubbers and reduce or eliminate any overloading of this control equipment. Better removal of chlorine aerosols from the discharge gases from the scrubbers may be achieved by use of high-efficiency demisters.

Control of styrene and acrylonitrile from the Marbon Chemical plant can be achieved by use of a condenser to recover usable products and an independently fueled flare for the discharge gases as they pass from the condenser to the atmosphere. Suitable safety considerations must be included in any design of flare equipment.

A major manufacturer of styrene has developed methods of controlling atmospheric emissions of styrene from storage tanks or loading operating when emissions are near bromine or chlorine discharges. Styrene is bulk-stored under an inert atmosphere of nitrogen.[28] The tank breathing of the inert atmosphere containing styrene traces is done by passing the vent gas through an independently fueled flare to destroy all styrene.[28,29] The manufacturer also monitors styrene concentrations at four stations around the bulk-loading facilities and shuts down loading operations whenever styrene is more than 2 parts per billion and whenever winds blow toward the sources of bromine and chlorine

Emissions from process vessels of the Shell Chemical plant and of the E. I. du Pont plant can be reduced by use of condensors to recover usable products and flares as described previously.

VI. REFERENCES

1. Personal communication, Drape, F. T., Ashland Chemical Company, Division of Ashland Oil and Refining Company, Houston, Texas, Sept. 18, 1969.

2. Drogin, I., "Carbon black," JAPCA, 18:222, April 1968.

3. Burhouse, W. A., "Hydrogen sulfide and mercaptan as air pollutants," presented at American Institute of Chemical Engineers, National Meeting, Detroit, Michigan, Dec. 8, 1968.

4. Huey, N. A., "The lead dioxide estimation of sulfur dioxide pollution," JAPCA, 18:610, Sept. 1968.

5. U.S. DHEW, Air Quality Criteria for Particulate Matter, NAPCA Pub. No. Ap-49, Jan. 1969, pp. 9-12.

6. Robinson, Elmer, "Effect on the physical properties of the atmosphere" IN: Stern, A. C., ed., Air Pollution, Chapter 11, pp. 349-400. Academic Press, N. Y., 1968.

7. Middleton, J. T., "Biological systems for the identification and distribution of air pollutants," IN: Problems and Control of Air Pollution, 64-68, Reinhold Corp., N. Y., 1955.

8. Middleton, J. T., and A. E. Paulus, "The identification and distribution of air pollutants through plant response," AMA Archives of Ind. Health, 14:526-532, 1956.

9. Hindawi, Ibrahim J., "Injury by sulfur dioxide, hydrogen fluoride, and chlorine as observed and reflected on vegetation in the field," APCA Journal, Vol. 18, No. 5, May, 1968.

10. Brennan, E., I. A. Leone, and R. H. Daines, "Chlorine as a phytotoxic air pollution," Pergamon Press (Great Britain), Int. J. Air-Water Poll., 9:791-797, 1965.

11. Zimmerman, P. W., Proceedings of the First National Air Pollution Symposium, L. A. (Standard Res. Inst.), 135, 1949.

12. Schmidt, H., Beobachtung uber Gasschaden an Obstbaumen. Dt. Baumsch. 3:10, 1951.

13. Thornton, N. C. and C. Setterstrom, "Toxicity of ammonia, chlorine, hydrogen cyanide, hydrogen sulphide, and sulphur dioxide gases. III. Green Plants, Contrib. Boyce Thompson Inst., II (5) 343, 1940.

14. Zimmerman, P. W., "Impurities in the air and their influence on plant life," Proc. of First Natl. Air Pollution Symp., Pasadena, Calif., p. 135, 1949.

15. Thomas, M. D., "Effects of air pollution on plants," World Health Organization, Monograph Series No. 46, Columbia University Press, New York, New York, 1961.

16. Thomas, M. D., R. H. Hendricks, and G. R. Hill, "Some impurities in the air and their effects on plants." Air Pollution, McCabe, L. C., ed., McGraw-Hill, New York, 1952, pp. 41-47.

17. Brewer, R. F., F. B. Sutherland, Guillement, and R. K. Creveling, "Some Effects of hydrogen fluoride gas on bearing navel orange trees," Proc. Am. Soc. Hort. Sci., 76:208-214, 1960.

18. Largent, Edward J., "The effects of air-borne fluorides on livestock" IN: McCabe, Louis, ed., "Air Pollution" Chapter 6, pp. 64-72. McGraw-Hill, 1952.

19. Gatcott, E. J., Effects of Air Pollution on Animals, World Health Org., Mono. Series No. 46, 1961.

20. Bellack, E. & P. J. Schouboe, "Rapid photometric determination of fluoride in water," Anal. Chem. 30:2032-4, 1958.

21. Weinstein, L. H., et al., "A semi-automated method for the determination of fluoride in air and plant tissues," Contrib. Boyce-Thompson Inst., 22:207-220, 1963.

22. Prince, A. L., F. E. Bear, E. G. Brennan, I. A. Leone, and R. H. Daines, Soil Science, 67:269, 1949.

23. Huey, Norman A., et al., "Objective odor pollution control investigations," J. Air Pollution Control Assoc., 10:441, 1960.

24. Threshold limit values of air-borne contaminents for 1969. American Conference of Governmental Industrial Hygienists.

25. Lionardos, G., D. Kendal, and N. Barrard, JAPCA, 19:91, 1969.

26. Hegrath, F. F., "The halogens," Industrial Hygiene and Toxicology, Vol. II, pp. 847-849, revised edition. Interservice Publications, N. Y., 1962.

27. Anonymous, "Report of air pollution and smoke prevention association of american," Chemical and Engineering News, 30:2704-05, 1952.

28. Shelley, P. G., and E. J. Sills, "Monomer storage and protection," Chemical Engineering Progress, 65:29, April 1969.

29. Personal communication, P. G. Shelley, Dow Chemical Company, Freeport, Texas, August 29, 1969.

30. Grant, W. M., Toxicology of the Eye, Charles C. Thomas, Springfield, Ill., 1962, p. 16.

31. Ibid, p. 241.

VII. APPENDICES

A. RECOMMENDATIONS OF 1967 ABATEMENT CONFERERENCE
B. AERIAL SAMPLING EQUIPMENT AND PROCEDURES
C. AIR QUALITY MEASUREMENTS

APPENDIX A.

RECOMMENDATIONS OF 1967 ABATEMENT CONFERENCE

PARKERSBURG, WEST VIRGINIA - MARIETTA, OHIO

INTERSTATE AIR POLLUTION ABATEMENT CONFERENCE

The attached findings and recommendations are those reached by the official participants to the Parkersburg, West Virginia - Marietta, Ohio, interstate air pollution abatement conference, and read into the record of the conference on March 23, 1967.

RECOMMENDATION I

INTERSTATE AIR POLLUTION CONTROL AGENCY

The Conference participants find:

1. That in the Parkersburg, West Virginia - Marietta, Ohio, area air pollution originating in either the State of West Virginia or the State of Ohio endangers the health and welfare of persons in both states.

2. That uniform standards and enforcement of control measures are required to obtain a uniform quality of air throughout the metropolitan region and to insure that no portion of the area provides a haven for pollution sources. To accomplish this, an agency must be established and vested with adequate legal authority. Legislation by the two States is needed to create such an agency.

Therefore, the conference participants concurred in the need for:

A. Legislation to establish an interstate air pollution control agency which, in addition to other appropriate authority, will be provided with:

1. Authority to establish uniform ambient air quality standards for at least the two county area involved in this abatement conference, i.e., Wood County, West Virginia, and Washington County, Ohio. Additional authority reasonably might be provided to authorize the interstate agency to include additional counties or to delimit as air pollution control regions other border areas in both States which share an air pollution problem, and to establish uniform air quality standards for such other regions.

2. Adequate rule-making and enforcement authority to abate, control and prevent air pollution originating in the bi-county Parkersburg - Marietta region (and in such other regions as the interstate air pollution control agency may establish) to assure the achievement of such air quality standards.

3. Authority to establish a regional enforcement agency in the Wood-Washington County region (and in any other region established by the interstate agency), with appropriate representation of local governments, which will meet the enforcement standards of the interstate agency and will be supported by local financial resources.

4. Assurance of adequate budgetary support by the States.

5. Federal representation with the same vote as any State, in recognition of the ultimate Federal interest in, and responsibility for, the quality of the air as it affects health or welfare of any persons.

RECOMMENDATION II
REFUSE DISPOSAL

The conference participants find:

1. That salvage operations and municipal, domestic, commercial, and industrial burning of refuse contribute to the overall air pollution burden in the Parkersburg - Marietta, Ohio, area and is the cause of specific localized problems.

2. That the burning of refuse in open dumps and in backyard incinerators occurs under extremely poor combustion conditions which result in releases of dense smoke and other pollutants that cause localized problems and add to general air pollution in the area.

3. That open fires, started intentionally or accidentally, occur at various dump sites, and contribute to air pollution in the interstate area.

4. That proper methods for salvage operations and refuse disposal are currently available; namely, utilization of multiple chamber incinerators or properly operated and maintained sanitary landfills.

Thrrefore, the conference participants recommend:

A. That salvage operations and the disposal of municipal, domestic, commercial, or industrial refuse by open burning be prohibited in the Parkersburg, West Virginia - Marietta, Ohio interstate area. It is desirable that this prohibition become effective within six months, but in no case shall open burning be permitted later than one year after the date of issuance of this recommendation by the Secretary of Health, Education, and Welfare.

B. That any device for salvage operations or for disposal of refuse by burning emit no more than 0.2 grain of particulate matter per standard dry cubic foot of exhaust gas corrected to 12 percent CO_2.

RECOMMENDATION III
CONTROL OF EMISSIONS FROM EXISTING, ALTERED OR NEW POWER OR STEAM GENERATING PLANTS

The conference participants find:

1. That in order to protect the health and welfare of residents in other similar areas, adoption of ambient air quality objectives for particulates and sulfur oxides has been implemented.

These criteria provide that:

A. For suspended particulates 50% of the 24-hour values shall be less than 80 $\mu g/m^3$ and 84% of the 24-hour values shall be less than 120 $\mu g/m^3$, for any consecutive 3-month period.

B. For settleable particulates, a dustfall of 15 tons/mi^2/month above background for residential areas, and 30 tons/mi^2/mo. above background for industrial areas shall not be exceeded.

C. For sulfur oxides, the 24-hour average concentrations shall not exceed 0.1 ppm by volume more than 1% of the time and shall not exceed 0.25 ppm by volume on an hourly basis more than 1% of the time.

2. That these levels are consistently reached or exceeded in the survey area.

Therefore, the conference participants recommend:

A. That the particulate emissions from all existing, altered, or new power or steam generating plants in the Parkersburg, West Virginia - Marietta, Ohio interstate area not exceed the limits set forth in Regulation II, Chapter 16-20, series II (1966), of the West Virginia Air Pollution Control Commission beyond October 1, 1968.

B. That all existing power or steam generating plants in the Parkersburg, West Virginia - Marietta, Ohio interstate area not be permitted to burn fuel having in excess of 2.0% sulfur by weight beyond October 1, 1968, unless they have installed effective means to control sulfur oxide emissions (calculated as sulfur dioxide) to an equivalent level.

C. That all new or expanded steam generating plants in the Parkersburg, West

Virginia - Marietta, Ohio interstate area not be permitted to burn fuel having in excess of 1.5% sulfur by weight following the issuance of this recommendation by the Secretary of Health, Education, and Welfare, unless they have installed effective means to control sulfur oxide emissions (calculated as sulfur dioxide) to an equivalent level.

RECOMMENDATION IV
CONTROL OF PROCESS EMISSIONS

The conference participants find:

1. That industrial process sources contribute malodorous or toxic gases and particulate emissions in such quantities as to require control measures.

2. Technological means for reducing or eliminating these emissions generally are available.

The conference participants recommend that:

A. Pollutant discharges into the atmosphere from any source in the Parkersburg, West Virginia - Marietta, Ohio area shall not exceed a density of 40% opacity, such opacity being that which obscures an observer's view to a degree equal to an emission designated as No. 2 on the Ringelmann Smoke Chart or on the Public Health Service Smoke Inspection Guide.

B. Pollutant discharges into the atmosphere from any source in the Parkersburg, West Virginia - Marietta, Ohio interstate area shall not cause to tend to cause injury, damage, detriment, nuisance, or annoyance to people, business, or property.

C. Within 18 months after the issuance of this recommendation by the Secretary of Health, Education, and Welfare, the above limitations shall apply to all process sources in the Parkersburg, West Virginia - Marietta, Ohio interstate area.

D. All sources shall submit written reports of progress toward accomplishment of this recommendation to the Ohio State Board of Health and the West Virginia Air Pollution Control Commission, 30 days, 90 days, and subsequently at 90-day intervals following issuance of these recommendations until compliance is reported, and shall forward a copy to the Presiding Officer of the Parkersburg, West Virginia - Marietta, Ohio Interstate Air Pollution Abatement Conference, Public Health Service, Washington, D. C. 20201.

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APPENDIX B.
AERIAL SAMPLING EQUIPMENT AND PROCEDURES

A Bell J4 helicopter was used in November 1968 and a Cessna 182 fixed-wing aircraft in January 1969. The same sulfur dioxide, temperature and altitude sensors were used in both periods. In January a particle counter was added to the equipment package.

The sulfur dioxide sensor was a Sign X Lab conductivity device with a nominal response time of about 2 seconds. The particle sensor was a Bausch and Lomb 40-1 Optical Particle Counter with response time of less than 1 second. It was capable of counting the number of particles with equivalent diameters greater than 0.3, 0.5, 1, 2, 3, 5 and 10 microns. The upper limit of the counter was one million (10^6) particles per cubic foot. All data were automatically recorded except the aircraft's geographical position, which was carefully and precisely maintained in the aircraft observer's log.

A survey flight consisted of a temperature sounding upon take off from Stewart Air Park to obtain atmospheric stability (by measuring the rate of change of temperature with height). The sounding was terminated when an inversion was encountered that was effectively confining the dispersion of the pollutants in the vertical direction. A visual inspection was made of the distribution of particulate pollutants.

The sampling aircraft proceeded to the vicinity of the major sources of sulfur dioxide and made traverses normal to their plumes at increasing distances downwind. Traverses were often repeated at different altitudes so that the configuration of the plume could be defined as precisely as possible. Then the plume was followed until it was no longer possible to detect it with assurance. Each survey flight included several minutes sampling outside any detectable plume to establish background contamination and define relatively uncontaminated areas. Another temperature sounding was made prior to landing.

It was possible to sample closer to the ground with the helicopter than with the fixed-wing aircraft. However, because the aircraft flew at 90 mph versus 50

mph for the helicopter (and for longer periods of time), a greater area could be sampled with the aircraft. Normally the length of the flight was about 2 hours for the helicopter and about 3 hours for the aircraft.

APPENDIX C.
AIR QUALITY DATA

Table C-1. MONTHLY SULFATION DATA

Location[a]		Sulfation rate, mg SO_3/100 cm^2-day	
X	Y	April, 1969	May, 1969
39.6	39.7	1.1	0.9
37.0	39.6	0.8	0.6
32.3	39.7	1.2	-
30.7	39.6	1.0	0.5
27.6	40.3	1.2	0.8
25.6	38.6	0.7	0.9
25.7	36.0	0.6	0.9
25.1	32.6	0.8	0.6
28.4	32.6	0.7	0.8
30.3	35.6	1.0	0.9
28.2	35.8	0.5	0.6
28.9	37.8	0.8	0.9
31.3	37.0	0.5	0.5
32.8	37.7	0.6	0.4
35.3	37.3	0.7	0.9
36.2	37.3	0.8	1.0
38.8	37.2	0.7	0.9
35.8	32.7	0.7	0.9
31.8	33.2	1.2	-
28.3	30.2	0.6	0.6
22.8	32.5	0.7	0.9
20.1	29.2	0.5	0.4
19.1	27.2	0.6	-
17.8	27.7	0.5	0.4
19.2	24.3	-	0.5

[a]Use site coordinates X and Y to locate sampling stations in Figure 1.

Table C-1 (continued). MONTHLY SULFATION DATA

Location[a]		Sulfation rate, mg SO_3/100 cm^2-day	
X	Y	April, 1969	May, 1969
19.8	22.4	-	0.4
21.7	23.8	-	0.5
25.3	27.5	-	0.5
28.9	25.0	-	0.6
51.3	56.6	-	1.1
50.4	53.2	0.7	0.5
52.7	49.7	0.7	0.2
55.2	50.4	0.7	0.6
58.3	49.7	0.7	1.1
53.8	56.3	0.6	0.4
62.0	50.7	0.7	0.9
61.0	49.3	0.8	0.9
52.6	47.1	1.0	1.1
55.0	45.2	0.3	0.5
58.2	42.3	0.6	0.4
61.3	41.2	0.6	0.5
63.2	38.2	0.5	0.5
57.4	37.6	0.6	0.2
53.9	38.0	0.7	0.8
50.7	35.6	0.6	0.6
47.8	37.3	0.6	0.8
45.5	40.1	0.7	0.8
42.7	40.4	0.5	0.8
43.1	36.7	0.6	1.0
44.0	35.0	0.6	0.8

[a]Use site coordinates X and Y to locate sampling stations in Figure 1.

Table C-1 (continued). MONTHLY SULFATION DATA

Location[a]		Sulfation rate, mg SO_3/100 cm^2-day	
X	Y	April, 1969	May, 1969
46.3	32.0	< 0.2	0.5
50.5	30.7	0.6	0.2
40.0	20.0	0.6	0.4
40.6	25.2	< 0.2	0.4
41.7	29.0	0.7	0.5
40.0	32.3	0.7	0.2
40.2	35.8	0.6	0.4
48.5	39.7	0.6	0.4
49.0	44.2	< 0.2	0.2
46.3	46.6	0.6	0.6
54.2	59.5	0.7	0.6
55.6	55.6	0.7	0.6
61.8	52.8	0.8	0.6
66.9	56.3	0.9	0.6
64.8	54.4	0.9	0.4
74.1	58.0	1.2	0.9
79.8	65.8	0.8	0.8
85.2	68.9	-	0.5
76.9	62.0	0.7	0.8
49.2	61.0	0.7	0.4
44.1	55.0	2.5	1.1
43.8	54.8	2.1	0.6
43.4	54.7	5.4	3.0
43.0	54.5	7.2	2.9
42.6	54.3	1.5	0.8

[a]Use site coordinates X and Y to locate sampling stations in Figure 1.

Table C-1 (continued). MONTHLY SULFATION DATA

Location[a]		Sulfation rate, mg SO_3/100 cm^2-day	
X	Y	April, 1969	May, 1969
41.9	54.0	0.8	0.5
40.4	53.4	1.1	0.5
38.8	51.6	1.1	0.9
38.0	48.2	0.8	0.8
37.5	45.1	0.8	0.6
38.2	46.8	0.7	0.6
38.3	50.2	0.8	0.1
44.1	56.1	2.6	1.0
43.1	56.6	1.3	0.6
40.3	55.7	0.6	0.5
40.6	54.9	0.4	0.8
39.1	53.7	0.9	0.4
37.8	53.3	0.6	0.4
37.8	54.2	1.2	0.4
36.5	52.9	-	0.4
35.2	51.7	1.3	0.8
36.2	51.3	0.7	0.6
35.5	50.9	0.5	-
31.9	49.7	0.6	0.6
37.3	41.7	0.4	0.4
37.3	41.0	0.7	0.1
37.3	40.7	0.4	<0.2
36.6	40.4	0.7	0.5
34.7	40.9	0.7	0.5
33.4	41.2	0.8	0.4

[a]Use site coordinates X and Y to locate sampling stations in Figure 1.

Table C-1 (continued). MONTHLY SULFATION DATA

Location[a]		Sulfation rate, mg SO_3/100 cm^2-day	
X	Y	April, 1969	May, 1969
31.0	41.3	0.7	0.5
29.9	41.2	0.7	0.1
36.3	42.3	1.0	0.4
35.4	42.1	0.7	0.6
32.8	42.2	0.7	0.8
30.4	42.0	0.9	1.4
33.2	41.3	0.8	0.8
34.6	43.4	0.6	0.8
34.2	44.4	0.6	0.6
33.8	45.0	1.4	0.4
32.0	45.5	0.7	0.4
31.9	44.0	0.7	0.4
30.1	43.6	0.9	0.5
27.4	45.1	0.9	0.6
27.6	42.7	0.8	0.5
26.2	41.6	0.8	0.1
23.9	39.0	0.8	0.6
23.0	38.2	0.8	0.6
22.7	34.8	0.7	0.2
22.3	33.3	<0.2	0.5
20.9	32.3	0.6	0.1
18.0	29.7	0.5	0.5
15.9	30.7	0.6	0.1
14.0	33.1	0.5	0.1
12.8	33.5	0.7	0.5

[a]Use site coordinates X and Y to locate sampling stations in Figure 1.

Table C-1 (continued). MONTHLY SULFATION DATA

Location[a]		Sulfation rate, mg SO_3/100 cm^2-day	
X	Y	April, 1969	May, 1969
17.5	35.2	0.7	0.6
21.6	37.0	0.6	0.6
23.9	39.9	0.7	0.5
17.0	48.7	0.6	< 0.2
09.9	56.3	0.7	0.1
09.9	60.6	0.7	0.4
26.1	58.0	0.7	0.4
26.2	56.6	0.8	0.4
26.0	54.7	0.7	< 0.2
26.0	50.1	0.6	0.8
21.7	49.6	1.4	0.8
26.2	48.1	1.0	0.5
26.3	52.3	0.7	0.4
32.2	57.3	0.7	< 0.2
38.6	57.4	0.8	0.2
43.3	59 5	0.7	0.1
47.3	59.5	0.8	0.5
54.0	62.9	0.8	0.5
58.0	63.7	0.8	0.8
62.0	66.1	0.4	0.5
64.3	69.8	< 0.2	0.5
69.7	71.2	< 0.2	0.6
74.6	70.3	< 0.2	0.2
70.8	65.5	0.6	0.5
62.3	61.5	< 0.2	0.5

[a]Use site coordinates X and Y to locate sampling stations in Figure 1.

Table C-1 (continued). MONTHLY SULFATION DATA

Location[a]		Sulfation rate, mg SO_3/100 cm^2-day	
X	Y	April, 1969	May, 1969
50.0	59.3	0.9	0.5
47.5	57.6	1.3	0.9
46.7	54.8	1.4	1.0
45.8	53.7	2.1	0.8
44.3	53.6	-	0.4
45.7	54.7	1.3	0.9
46.8	55.8	1.1	1.4
43.5	52.8	1.3	0.4
42.1	51.0	1.4	0.6
40.2	50.8	0.9	0.6
40.1	49.3	0.8	0.6
40.0	45.2	0.9	0.9
46.7	93.4	0.8	0.5
46.2	95.7	0.7	0.2
45.3	96.6	0.7	0.2
42.0	99.0	< 0.2	0.4
37.6	98.5	1.2	0.6
36.8	92.0	1.2	1.1
33.4	84.2	1.3	1.2
29.2	78.7	0.7	0.8
12.1	89.2	1.0	0.5
03.6	92.2	< 0.2	0.5
21.4	85.0	< 0.2	0.9
18.3	76.7	1.1	0.6
15.1	83.8	0.9	0.6

[a]Use site coordinates X and Y to locate sampling stations in Figure 1.

Table C-1 (continued). MONTHLY SULFATION DATA

Location[a]		Sulfation rate, mg SO_3/100 cm^2-day	
X	Y	April, 1969	May, 1969
18.0	85.5	0.2	-
24.8	88.4	2.6	1.1
23.0	91.0	1.9	0.9
24.3	96.5	1.6	0.6
27.7	95.4	1.7	1.0
30.0	99.1	1.2	0.6
34.3	81.8	1.1	0.4
33.4	79.4	0.8	0.4
40.5	82.3	1.4	-
43.2	77.0	0.7	0.4
46.2	82.7	1.4	1.0
50.1	77.3	1.3	0.8
50.7	71.4	1.4	0.6
47.4	61.4	1.2	0.8
46.2	62.6	1.7	-
42.2	63.7	1.1	0.5
38.9	67.8	1.7	1.5
33.2	74.0	1.2	0.6
21.2	83.7	0.7	0.6
19.6	79.2	0.7	0.5
23.3	79.4	1.3	1.0
24.3	81.7	0.9	0.4
24.8	82.4	0.7	0.2
26.8	75.8	0.6	0.2
29.0	67.0	-	0.5

[a]Use site coordinates X and Y to locate sampling stations in Figure 1.

Table C-1 (continued). MONTHLY SULFATION DATA

Location[a]		Sulfation rate, mg SO_3/100 cm^2-day	
X	Y	April, 1969	May, 1969
20.3	58.2	1.0	0.8
10.8	60.0	0.7	0.5
30.9	64.2	0.7	0.5
50.6	65.2	-	0.5
45.1	67.7	0.7	0.6
42.7	74.5	0.8	0.4
34.2	68.5	1.2	0.8
38.8	62.3	-	1.1
48.5	62.3	0.8	0.8
52.0	61.6	-	0.5
51.2	63.2	0.8	0.6
56.0	70.3	0.9	0.6
61.6	74.3	0.8	0.9
42.8	52.6	0.9	0.2
41.1	51.6	0.5	0.8
42.2	48.9	0.7	0.4
44.4	51.4	0.7	0.4
41.0	49.8	0.7	0.6
38.9	47.8	0.8	1.0
40.5	46.9	0.7	0.6
41.4	46.8	1.0	0.9
42.8	45.5	1.2	0.8
41.3	45.3	-	0.6
39.5	45.7	<0.2	0.5
39.1	43.8	<0.2	0.6

[a]Use site coordinates X and Y to locate sampling stations in Figure 1.

Table C-1 (continued). MONTHLY SULFATION DATA

Location[a]		Sulfation rate, mg SO_3/100 cm^2-day	
X	Y	April, 1969	May, 1969
40.3	42.3	0.8	0.4
41.9	43.3	1.1	0.6
38.3	41.8	0.7	0.6
38.0	40.7	0.8	0.6
40.2	40.5	0.7	0.6
42.3	41.6	0.9	0.5
43.6	42.3	<0.2	0.4

[a]Use site coordinates X and Y to locate sampling stations in Figure 1.

Table C-2. EFFECTS SURVEILLANCE DATA FROM PARKERSBURG, WEST VIRGINIA, AND MARIETTA, OHIO STATIONS[a]

Lead peroxide candle, mg SO_3/100 cm^2-day

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Arith. mean	Max. value
Parkersburg														
1966	0.6	0.6	-	0.5	0.6	0.4	0.5	0.5	1.6	0.4	0.6	0.9	0.6	1.6
1967	0.5	0.7	0.5	0.5	0.7	0.4	0.3	0.5	0.5	0.4	0.5	0.6	0.5	0.7
1968	1.1	0.9	1.9	0.5	0.4	0.4	0.6	0.2	0.3	0.3	0.5	0.5	0.6	1.9
Marietta														
1966	0.6	0.7	0.5	0.6	0.8	0.7	1.0	0.8	0.4	0.5	0.5	1.1	0.7	1.1
1967	0.6	1.0	0.7	0.7	0.7	0.6	0.7	0.6	0.7	0.4	Void	0.6	0.7	1.0
1968	1.4	1.1	0.8	0.7	0.6	0.6	0.7	0.8	0.5	0.9	-	-	0.8	1.4

Dustfall, tons/mi^2-day

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Arith. mean	Max. value
Parkersburg														
1966	11	15	19	20	18	7	19	13	10	18	14	12	15	20
1967	-	24	35	24	18	14	19	6	10	26	16	17	19	35
1968	14	19	26	25	22	17	23	19	13	19	18	20	20	26
Marietta														
1966	12	17	20	24	24	14	21	13	9	17	12	9	16	24
1967	12	14	20	23	25	15	13	10	12	12	20	9	15	25
1968	13	14	20	26	6	13	14	17	11	25	11	13	15	26

Table C-2 (continued). EFFECTS SURVEILLANCE DATA FROM PARKERSBURG, WEST VIRGINIA, AND MARIETTA, OHIO STATIONS[a]

Silver tarnishing reflectance, % loss

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Arith. mean	Max. value
Parkersburg														
1966	58	66	67	60	67	77	70	65	48	63	65	56	64	77
1967	65	77	47	75	70	92	79	87	53	82	54	78	72	92
1968	69	55	72	85	71	77	84	74	75	78	74	76	74	85
Marietta														
1966	33	61	48	49	68	67	63	70	47	46	37	64	54	70
1967	52	44	67	49	62	68	60	87	73	44	35	38	56	87
1968	71	33	45	76	49	57	71	71	63	65	48	47	58	76

Steel corrosion weight loss, per 3- by 4-in. panel, mg/day

	Jan.-Mar.	Apr.-June	July-Sept.	Oct.-Dec.	Arith. mean	Max. value
Parkersburg						
1966	13.5	16.0	17.6	23.9	17.7	23.9
1967	15.5	14.1	21.0	11.1	15.4	21.0
1968	16.6	18.0	21.3	17.0	18.2	21.3
Marietta						
1966	16.6	20.7	31.0	22.9	22.8	31.0
1967	17.5	20.7	31.1	0.9	17.6	31.1
1968	14.6	52.7	27.7	25.7	30.2	52.7

[a]Interstate effects surveillance network, National Air Pollution Control Administration.